

LOW-LEVEL RADIATION: ARE CHEMICAL OFFICERS
ADEQUATELY TRAINED?

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

LOW-LEVEL RADIATION: ARE CHEMICAL OFFICERS ADEQUATELY TRAINED?

by MAJ John D. Shank, 94 pages.

The United States Army Chemical School provides radiological training to lieutenants and captains in the Chemical Officer Basic Course (CBOLC) and the Chemical Captain's Career Course (CMC3). Most of the radiological terminal learning objectives for the courses are focused on nuclear weapons and their effects. Chemical officers have to be able to provide timely and accurate advice to their Commanders on the low-level radiation hazards as well as the high-level radiological hazards like those resulting from nuclear detonations. Low-level radiological sources can present physical health hazards and there can be adverse psychological impacts if individuals believe that they may have been exposed and adequate responses are not initiated.

This thesis analyzed the Programs of Instruction (POIs) for the two courses to determine what low-level radiological training is currently being conducted and to develop recommendations for additional radiological training that should be added or integrated into the existing courses. This thesis determined that additional low-level radiation training for both chemical lieutenants and captains is required. The radiological training currently being taught does not provide adequate information for chemical officers to properly advise their commanders on the low-level radiation threat. This thesis also determined that some military publications need to be revised.

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I take full responsibility for this thesis. Any errors or omissions on this thesis are my own.

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ACRONYMS

ALARA	As Low As Reasonably Achievable
BEIR	Biological Effects of Ionizing Radiation
CBOLC	Chemical Basic Officer Leadership Course
cGy	Centigray
CMC3	Chemical Captain's Career Course
DU	Depleted Uranium
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
LLR	Low-level Radiation
mGy	Milligray
mrad	Millirad
mrem	Millirem
mSv	Millisievert
NCRP	National Council on Radiation Protection and Measurements
NRC	US Nuclear Regulatory Commission
POI	Program of Instruction
R	Roentgen
RDD	Radiological Dispersal Device
RES	Radiation Exposure Status
STANAG	Standardized Agreement
Sv	Sievert
WMD	Weapons of Mass Destruction

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CHAPTER 1

INTRODUCTION

For almost sixty years, the United States (US) Army has planned and trained to operate on a nuclear battlefield. The United States government developed munitions that could deliver a nuclear warhead and worked to increase the efficiency and yield of the warhead while at the same time reducing its size and weight. Army Commanders practiced procedures that would allow them to integrate a nuclear attack into their battle plan and defeat the enemy.

One of the Army's interests in pursuing the ability to employ nuclear weapons was for their blast and thermal effects. Eighty-five percent of the energy released from a nuclear explosion is in the form of blast and thermal effects. Only 4 percent of the nuclear burst energy was in the form of initial radiation and 10 percent of the energy was in the form of residual radiation (FM 3-3-1 1994a).

The Army was concerned about the high levels of radiation exposure that soldiers would receive during a nuclear attack. Lower levels of radiation were considered not militarily significant; they would not affect the current battle. That is not to say that there would not be any long-term effects from radiation or that lower levels of exposure were unimportant. The commander's focus was to be able to survive a nuclear strike and defeat the enemy.

Chemical soldiers are taught how to plot the predicted radiological fallout zones from a nuclear explosion. Outside of the predicted fallout zone Army Field Manual (FM) 3-3-1 states, "The total dose for an infinite time of stay outside the predicted area should

not reach 150 centigray (cGy). Therefore, outside the predicted area, no serious disruption of military operations is expected to occur if personnel have not previously been exposed to nuclear radiation” (1994a). Contrast this level of radiation with what the U.S. government says is acceptable for civilians that work in the nuclear industry. The Nuclear Regulatory Commission (NRC) authorizes occupational radiation workers in the US to receive a dose of five cGy per year. In this example the 150 cGy is not an authorized limit, and the Army is not saying that there will not be any health effects from the radiation exposure. It is simply a statement that even at that high level there should not be a disruption of current military operations caused by the physiological effects of radiation exposure.

Context of the Problem

Low-level radiological (LLR) materials are very common in society today. Industrial societies as well as third world countries use LLR materials in everything from the smoke detectors in homes to engineering equipment used to build roads. There are many legitimate uses for products that contain radioactive sources and the number of different products manufactured each year that contain radioactive sources continues to grow.

Low-level radioactive sources were found in Baghdad, Iraq, during Operation Iraqi Freedom. The sources had to be secured at their current locations once it was identified that they really were radioactive. During the first several months of the operation the Army did not have an approved location to transport them to for long-term storage, so the ground tactical units were required to secure them by maintaining a guard

on them twenty-four hours a day. This security requirement reduced the available combat power of the units.

Many soldiers and local civilians were concerned about the possible health effects of the radiation. They were afraid of the radiation and did not understand the level of danger that they were being exposed to or how it would affect them. This concern caused both the civilians and soldiers to take actions to try to protect themselves from the perceived threat even though they did not know if it was a legitimate concern or not.

Chemical officers are looked to as experts when it comes to chemical, biological, radiological, and nuclear (CBRN) operations. Chemical officers must be educated if they are expected to be able to provide accurate NBC information to their commanders. To compound the problem it can be assumed that if an NBC event has actually occurred it will be a highly stressful time for those chemical officers. In a training environment, the Army identifies the critical tasks that must be performed, the conditions that they have to be performed under, and the standard by which they will be judged. These tasks are incorporated into a program of instruction (POI) that the Army uses to list the tasks that will be taught in the different Army courses.

The Army must provide low-level radiological training if it expects chemical officers to know how to properly respond to a LLR event. The Army has principally focused their NBC training on the effects of nuclear weapons and not radiological incidents. Radiation theory and principles may be the same for low-level and high-level radiation incidents, but the proper response will probably be very different when responding to a nuclear detonation on a battlefield or a LLR event in a city, even if the reading at both locations is 1 cGy per hour.

The Research Question

When a weapon of mass destruction (WMD) CBRN threat is typically discussed by our national leaders or the media, the focus is usually on the chemical and biological threat and ways to mitigate that threat. The health effects posed by radioactive material or what the military would have to do to respond to an attack, to mitigate the effects, and to continue with their mission receive less discussion. This thesis asks the following question: Are United States Army chemical officers adequately trained to respond to a low-level radiation threat?

Subordinate Questions

In order to answer that question this thesis's first subordinate question is, What is radiation and how dangerous is it? Is the threat of low-level radiation real, and how does it affect people? For this question the literature review in chapter 2 begins by discussing the basics of radiation theory to provide a foundation for the discussion. It follows with a review of the physical and psychological effects and implications radiation exposure.

The second subordinate question is: What is the availability of LLR material in the world? This question will look at how and where radioactive items are used in society and how easy is it to obtain them. Should soldiers expect to encounter LLR materials while conducting military operations?

The third subordinate question is the credibility of the threat of the use of LLR material by a terrorist or other adversary. There are often stories in the newspaper about WMD and possible terrorist activity. For example the *Washington Times* had an article in which it claimed that a key al Qaeda terrorist suspect had been in Canada looking for material to make a "dirty bomb" (Gertz 2003). The suspect was planning to buy or steal

either radioactive material from a research reactor at one of the universities or radioactive medical waste from a hospital.

Once the level of threat of use by an adversary is identified, then the fourth subordinate question of this thesis asks: What radiological training do Army chemical officers receive? This thesis will discuss the radiation information and training that chemical lieutenants (LTs) receive during the Chemical Basic Officer Leadership Course (CBOLC) and captains (CPTs) receive at the Chemical Captain's Career Course (CMC3). Chemical LTs typically attend the CBOLC as their first assignment on active duty and CPTs attend CMC3 shortly after being promoted to CPT when they have been in the Army for approximately four years. In chapter 4 an analysis will be made of the radiation training and instruction the LTs and CPTs receive and the tasks that they may be required to undertake while conducting operations with their units.

Assumptions

This thesis makes some assumptions. The first assumption is that chemical officers are receiving adequate nuclear training to allow them to plot a nuclear detonation to predict the downwind hazard area, and to advise their commanders on the effects of nuclear explosions. This thesis also assumes that even these basic skills have not been practiced since the chemical officers completed their radiological block of instruction while attending CBOLC or CMC3. Another assumption of this thesis is that chemical officers have not received any substantial radiation instruction in addition what they received at CBOLC or CMC3. Finally, the recommendation to integrate and add additional LLR instruction to the CBOLC and CMC3 Programs of Instruction (POIs) are not constrained by a lack of time in the schedule to conduct the additional training.

Definitions

Listed below are some key terms that are important to define so the reader will have a common understanding. Some of the terms are familiar to military and civilian audiences, but others are not. These definitions, unless otherwise noted, are taken from the glossary of radiological terms in the *Chemical/Biological/Radiological Incident Handbook (October 1998)* found at the Central Intelligence Agency web site.

Alpha Particle. The alpha particle has a very short range in air and a very low ability to penetrate other materials, but it has a strong ability to ionize materials. Alpha particles are unable to penetrate even the thin layer of dead cells of human skin and consequently are not an external radiation hazard. Alpha-emitting nuclides inside the body as a result of inhalation or ingestion are a considerable internal radiation hazard.

Beta Particles. High-energy electrons emitted from the nucleus of an atom during radioactive decay. They normally can be stopped by the skin or a very thin sheet of metal.

Cesium-137 (Cs-137). A strong gamma ray source and can contaminate property, entailing extensive clean up. It is commonly used in industrial measurement gauges and for irradiation of material. Half-life is 30.2 years.

Cobalt-60 (Co-60). A strong gamma ray source that is extensively used as a radiotherapeutic for treating cancer, food and material irradiation, gamma radiography, and industrial measurement gauges. Half-life is 5.27 years.

Decay. The process by which an unstable element is changed to another isotope or another element by the spontaneous emission of radiation from its nucleus. This process can be measured by using radiation detectors, such as Geiger counters.

Decontamination. The process of making people, objects, or areas safe by absorbing, destroying, neutralizing, making harmless, or removing the hazardous material.

Dose. A general term for the amount of radiation absorbed over a period of time.

Dosimeter. A portable instrument for measuring and registering the total accumulated dose to ionizing radiation.

Gamma Rays. High-energy photons emitted from the nucleus of atoms, similar to x-rays. They can penetrate deeply into body tissue and many materials. Cobalt-60 and Cesium-137 are both strong gamma emitters. Shielding against gamma radiation requires thick layers of dense materials, such as lead. Gamma rays are potentially lethal to humans.

Half-Life. The amount of time needed for half of the atoms of a radioactive material to decay.

Highly Enriched Uranium (HEU). Uranium that is enriched to above 20 percent Uranium-235 (U-235). Weapons-grade HEU is enriched to above 90 percent in U-235.

Ionize. To split off one or more electrons from an atom, thus leaving it with a positive electric charge. The electrons usually attach to one of the atoms or molecules, giving them a negative charge.

Rad. A unit of absorbed dose of radiation defined as deposition of 100 ergs of energy per gram of tissue. It amounts to approximately one ionization per cubic micron.

Radiation. High energy alpha or beta particles or gamma rays that are emitted by an atom as the substance undergoes radioactive decay.

Radiation Sickness. Symptoms resulting from excessive exposure to radiation of the body.

Radioactive Waste. Disposable, radioactive materials resulting from nuclear operations. Wastes are generally classified into two categories, high-level and low-level waste.

Radiological Dispersal Device (RDD). A device (weapon or equipment), other than a nuclear explosive device, designed to disseminate radioactive material in order to cause destruction, damage, or injury by means of the radiation produced by the decay of such material.

REM. A Roentgen Equivalent in Man is a unit of absorbed dose that takes into account the relative effectiveness of radiation that harms human health.

Shielding. Materials (lead, concrete, etc.) used to block or attenuate radiation for protection of equipment, materials, or people.

Uranium 235 (U-235). Naturally occurring uranium U-235 is found at 0.72 percent enrichment. U-235 is used as a reactor fuel or for weapons; however, weapons typically use U-235 enriched to 90 percent. The half-life is 7.04×10^8 years.

Limitations

This research is limited to using unclassified materials and is focused on the training that LTs receive at CBOLC and CPTs receive at CMC3. There might be some benefit to reviewing classified information, but the intent of this thesis is to produce information that is available for wide dissemination. There are medical service officers and others that have radiological training and expertise, but this thesis will not cover the training they receive.

Delimitations

This research will not consider the radiological training the US Navy, US Air Force, US Marines, or the US Coast Guard provide their chemical officers. This research will also not consider the training that other nations provide the people in comparable positions as US chemical officers are in. The training that both the other services and countries provide may be beneficial to developing a comprehensive radiological training program, but will not be considered in this thesis due to time constraints, so that the research will be feasible.

Significance of the Study

An attack on the US using a radiological dispersal device (RDD) is a low probability, high consequence event. The military would most likely be called upon to respond and provide assistance to the lead federal agency. There would be both physical and psychological effects for an attack of which the psychological impact may dwarf the physical effects by comparison (NCRP 2001). The physical effects would probably affect only a relatively few individuals. Millions of people could feel the psychological effects all across the nation.

Low-level radiological sources are commonly used throughout the world, and soldiers can expect to encounter them while conducting military operations. Most radiological sources would not present a major hazard, but some of them are strong enough to present a danger and affect commander's decisions on the ground. The problem of dealing with radiological sources during military operations is not just a future possibility. It is a present reality in places like Iraq and Afghanistan.

This thesis will take a hard look at an area of officer training that the Army has not focused on until recently. Low-level radiological hazards have been considered a minor issue so the Army has not resourced the Chemical School with additional training time and funds to incorporate LLR information into their lesson plans. Chemical officers need to be trained to effectively advise their commanders on the radiological threat and actions to take to minimize that threat.

CHAPTER 2

LITERATURE REVIEW

To be able to adequately look at the subject of chemical officer radiological training, it is necessary to review the current literature on the subject and to identify what chemical officers are taught. This chapter will begin by discussing basic radiation theory to provide a common foundational basis of understanding. The chapter will then look at the FMs that discuss radiation and nuclear weapons. This chapter will also review information about the availability of radiological material and the threat of use of RDDs by an adversary. Appendixes A and B of this thesis are the US Army Chemical School's CBOLC and CMC3 radiological lesson plans. An analysis of this information in chapter 4 will examine the tasks that are being taught are adequate to properly prepare chemical officers for their assignments in tactical units.

Radiation Fundamentals

A discussion on radiation requires a common understanding of the fundamentals of radiation and how it can affect people and the environment. Most people know a little about radiation, but cannot provide specific answers if asked basic questions about it. They can tell you that it is dangerous and can kill you, but the typical person in the US cannot explain how much radiation they would have to receive to be affected or what would happen if they received a certain level of radiation.

All matter is made up of atoms. Atoms are made up of protons, neutrons, and electrons. In the center of an atom are positively charged protons and neutrons that, as the name implies, are neutrally charged. Together they are called the nucleus. These two

parts of the atom together make up almost all of the mass of the atom. Electrons orbit around the nucleus of the atom, like planets going around the sun, and carry a negative charge. Each proton in the nucleus is attracted to an electron. This gives the atom a neutral overall electrical charge since they have opposite electrical charges. The diameter of the atom is approximately 10,000 times the diameter of the nucleus. Because of this, the atom is composed mostly of empty space. See figure 1.

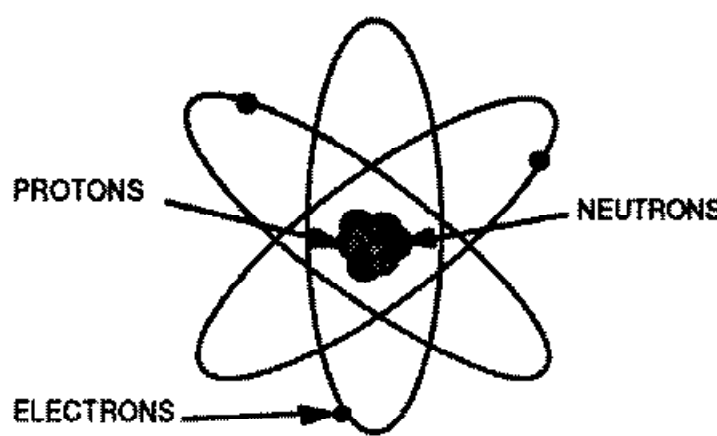


Figure 1. Diagram of an Atom

The earth is made up of ninety-two naturally occurring elements. The elements have from one proton in the nucleus, hydrogen, to ninety-two protons in the nucleus, uranium. Each element has a one or two letter symbol to signify that element. For example, the symbol for hydrogen is (H) and the symbol for uranium is (U).

Atoms of a particular element would like to be in a stable state. Atoms that have high mass numbers have a large amount of energy in their nucleus, which causes them to be more unstable and radioactive. The larger atoms will try to become more stable by

emitting alpha or beta particles. This process of releasing energy to become more stable is called radioactive decay.

Electrons orbit around the nucleus of the atom in specific shells. Each shell has a maximum number of allowable electrons in it, and the electrons always fill up the inner shells first before starting to fill the outer shells. Atoms would like to have their outermost shell full of electrons and can do so by either having electrons in the outermost shell captured by another atom or by sharing some electrons in its outermost shell with another atom. When two atoms share one or more electrons in their outermost shell, they become a molecule of an element or compound.

When an atom loses an electron both the atom and the free electron are called ions and the process is called ionization. The atom now has a positive charge, the electron has a negative charge, and they both tend to try to join with other atoms or ions. Ionization can split other atoms into positive and negative fragments that can form new chemical compounds. Inside the body, this can interrupt the function of cells and cause a biological effect. Alpha particles, beta particles, gamma rays, neutrons, and x-rays are all examples of ionizing radiation.

Alpha particles are the heaviest and most highly charged of the nuclear radiations. Alpha particles are made-up of two protons and two neutrons and are positively charged. Because they are so heavy, they can travel only a few inches through the air and have little penetrating power. When an alpha particle comes in contact with an object, like a piece of paper, all of its energy is spent interacting with the object at the surface, and the particle is not able to penetrate it.

The outer layer of skin cells on a person's body is made-up of dead skin cells. An Alpha particle cannot penetrate those cells and cause damage to the live cells that are underneath that outer layer of cells. An alpha particle would cause significant localized damage if it got into the body through inhalation or ingestion since the cells inside the body are alive. Alpha particles are considered an internal hazard and not an external hazard for this reason.

Beta particles are smaller and travel faster than alpha particles. This allows them to be able to travel about 10 feet through the air and penetrate further into an object. Beta particles are produced when a neutron in the nucleus decomposes into a proton and a beta particle. The proton remains in the nucleus, while the beta particle is expelled as energy. Beta particles can cause skin burns if the skin is exposed to large amounts of beta radiation for a long time. Beta particles are primarily considered internal hazards.

Gamma rays can travel up to a mile through the air at the speed of light and can penetrate through all types of materials. Gamma rays from a radioactive source located outside of the body can damage cells and organs inside a person's body. These gamma rays have no mass and no charge. They are pure electromagnetic energy.

Neutron radiation is a fourth type of radiation. The neutrons move through space and are not part of an atom. Neutrons give up their energy mostly by colliding with protons in the nucleus of hydrogen atoms. The nucleus of an atom captures the neutron when it has lost enough energy. This additional neutron makes that atom radioactive and it will give off alpha or beta radiation, gamma rays, or a combination of the three as it tries to become stable again.

The subject of radiation measurements is vital to an accurate understanding of the danger of radiation and the expected effect it will have on an exposed person. Problems dealing with radiological units of measure often arise since they are not commonly used and can be easily confused. Metric prefixes can also create problems for unfamiliar users. Table 1 shows the comparison between commonly used radiation measurements.

Table 1. Radiation Unit Conversions						
gray sievert	centiGy centiSv	milliGy milliSv	microGy microSV	rad rem	millirad millirem	microrad microrem
100	10,000	100,000		10,000		
10	1,000	10,000		1,000	1.00E+06	
5	500	5,000		500	500,000	
1	100	1,000	1.00E+06	100	100,000	
0.1	10	100	100,000	10	10,000	
0.01	1	10	10,000	1	1,000	1.00E+06
0.001	0.1	1	1,000	0.1	100	100,000
0.0001	0.01	0.1	100	0.01	10	10,000
0.00005	0.005	0.05	50	0.005	5	5,000
0.00001	0.001	0.01	10	0.001	1	1,000
	0.0001	0.001	1	0.0001	0.1	100
	0.00001	0.0001	0.1	0.00001	0.01	10
	0.000001	0.00001	0.01	0.000001	0.001	1
Read across to convert from one set of units to another.						
Gray is numerically equal to a sievert, and rad is numerically equal to a rem for beta and gamma radiations.						

A person's exposure to radiation can be limited using the three principles of radiation protection. The three principles are: time, distance, and shielding. Using one of the principles or a combination of them will reduce the total exposure a person receives.

A person can limit the time that they spend near a radioactive source if they want to reduce their exposure. The total radiation dose a person receives can be equated to the

intensity of radiation, dose rate, multiplied by the time exposed. By reducing one part of the equation, the time, the total exposure is reduced.

A person can increase the distance between themselves and the radioactive source if they want to reduce their exposure. The farther a person is away from the radioactive source the lower their exposure will be. In fact, for gamma rays when the distance from a radioactive source to a person is doubled, the radiation level received is reduced by a factor of four. For example, if the gamma radiation level one meter from a source is 100 cGy, the radiation level two meters from the radioactive source would be 25 cGy. A person can reduce their radiation exposure simply by moving farther away from the radioactive source.

A person can reduce their exposure to gamma radiation by increasing shielding. Shielding is putting something between a person and the radioactive source that will attenuate some of the radiation before it reaches the person. The denser a material, for example lead as compared to wood, the more effective it will be for shielding.

The amount of radiation attenuated by shielding also depends on the type of radiation. Alpha radiation is effectively shielded by a piece of paper, but beta and gamma are not (see figure 2). Gamma radiation can be significantly reduced but will not be completely shielded by even several inches of lead.

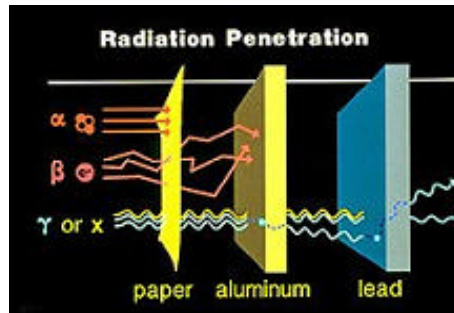


Figure 2. Shielding

There are many natural and man-made radioactive sources found in the environment. All of us are exposed to very small amounts of radiation each day. In the United States, people receive on average 360 mrem of radiation annually (US Environmental Protection Agency 2003). The primary types of natural background radiation are cosmic radiation, terrestrial, and radioactivity in the body. Table 2 shows how much radiation a typical person in the United States annually receives and their lifetime cancer risk.

The sun emanates not only light but radiation as well. The earth's atmosphere acts as a shield and filters much of the radiation, but some radiation still gets through. Different places receive different amounts of radiation based primarily on the elevation of that location. For example, people living in Denver, Colorado would receive more cosmic radiation than people living near the beach in Florida. This is because there is less atmospheric attenuation at higher altitudes to reduce the amount of radiation that reaches the earth.

Table 2. Annual Radiation Exposure		
Source	Dose Rate (mrem/yr)	Lifetime Cancer Risk assuming validity of LNT*
Indoor radon	200	7,500 per 1,000,000
Cosmic rays (at sea level)	30	1,100 per 1,000,000
Cosmic rays (Denver at 5000 ft elevation)	55	2,000 per 1,000,000
Human body (from food we eat)	40	1,500 per 1,000,000
Soil and rock	30 - 50	1,100 to 1,900 per 1,000,000
Soil and rock (Colorado plateau)	90	3,400 per 1,000,000
Living in a brick house	7	260 per 1,000,000
Working in granite buildings	50 - 200	1,200 per 1,000,000
One round trip from LA to NY	6	3 per 1,000,000
Smoking 1 pack of cigarettes/day (polonium-210)	8,000	200,000 per 1,000,000
Sleeping next to one's partner	2	50 per 1,000,000

* LNT. The linear-no-threshold (LNT) model of radiation risk assumes even the smallest incremental exposure to radiation has an associated cancer risk. There is no scientific evidence to support this theoretical model.

Source:(Rutherford 2002)

The earth contains radioactive materials. Some parts of the earth contain much higher quantities of radioactive elements, like uranium or thorium. The concentration varies depending on the type of rock formation in the region.

Many people are surprised to learn that a person's body contains very small quantities of radioactive carbon and potassium. These radioactive isotopes are found in minute quantities in the body and are not harmful. In fact, the trace radioactive elements help a person's body operate normally.

In addition to the naturally occurring radiation, there are many man-made radioactive sources. Doctors use diagnostic radiation, for example x-rays, to help

diagnose a patient's condition. Therapeutic radiation is used to treat cancer patients. The radiation treatment for cancer patients is very precise and targeted to the specific area of concern. A final example of radiation from man-made sources is occupational exposure that people receive that work around radioactive materials. Nuclear energy workers, industrial users of radioactive materials, and medical personnel are examples of people that might encounter radioactive materials as part of their jobs.

Biological Effects of Radiation Exposure

Several factors affect how much damage radiation causes to a person's body after exposure. Some of the factors include the amount of radiation received, type of radiation, length of time exposed, part of the body exposed, and biological variables unique to the individual exposed (American College of Radiology 2002). Two individuals can have dramatically different effects depending on these five factors.

The type and amount of radiation received both affect how the body responds. For example, alpha particles cause much more internal damage than gamma rays. The higher the dose of radiation a cell is exposed to, the greater the damage at the cellular level. A person's body is continually growing new cells and can repair many types of cell damage. The effects of radiation can be seen when the cells are either overwhelmed by the effects of the radiation and die or when the body improperly repairs the damaged cells (US NRC 2003).

Radiation exposure can be characterized as either an acute or a chronic dose. The length of time a person is exposed to a certain amount of radiation affects how the person's body responds to the radiation. An acute dose of radiation is one that occurs over a short period, usually less than twenty-four hours. A chronic dose is the amount of

radiation received over a longer period. A person would have less than a fifty-fifty chance of survival if exposed to 600 cGy over a twelve-hour period. There would be little or no attributable effects if the same exposure were to occur over twenty years.

The part of the body exposed and a person's biological variability factors will affect how the body responds to the radiation. The amount of tissue exposed will affect the body's response. Factors, like age, gender, and overall health, will also affect how a person's body is able to repair itself after exposure (US NRC 2003).

The Nuclear Regulatory Commission (NRC) and Army regulation limit the maximum allowable peacetime whole body radiation dose an individual can receive. For occupational radiation workers the annual whole body dose limit is 5 rem. The annual general public exposure limit is 100 mrem (0.1 rem) (US NRC 2003). This is in addition to natural background radiation.

The two primary health worries of people exposed to radiation are an increased cancer rate and possible genetic effects on their children (US NRC 2003). This is true even though there is no scientific data to demonstrate that there is an increase in cancer due to low-level radiation exposure below 10 rem (US NRC 2003). The survivors of Hiroshima and Nagasaki have been studied extensively to determine the long-term health effects of their exposure on themselves and their children. There is also no evidence of an increase in genetic defects among the survivors' children (US NRC 2003).

Psychological impact of radiation exposure

A radiological incident can produce dramatic psychosocial effects. The psychological reaction to a radiological dispersal device (RDD) could very likely affect not only individuals, but local communities and the whole country (NCRP 2001). An

RDD can produce fear, increase the sense of personal vulnerability, and make people feel a “loss of confidence in societal institutions” (NCRP 2001). Fear can force rational people to do very irrational things and respond in uncharacteristic ways. This is especially true when the object of a person’s fear is unknown to them or only superficially understood.

RDDs produce psychological effects for two primary reasons. The first reason is that people know that RDDs involve toxic hazards. The second reason is that they know that someone deliberately detonated the RDD with the intent of causing harm (NCRP 2001). These two reasons can cause serious psychological consequences in people.

Toxic hazards, like exposure to radiation, can be very frightening (Bromet 1998). People exposed to radiation from a RDD would be involuntary victims and would probably not have a thorough understanding of the true threat that they are facing. These two factors can increase personal levels of worry and concern (NCRP 2001). Radiation hazards can also be unnerving because radiation cannot be detected using the five senses.

People exposed to an RDD could be psychologically impacted knowing that it was a deliberate act and not an accident (NCRP 2001). A tragic event is easier to emotionally deal with if it is an act of God or accident as compared to an intentional act. Very high rates of post- traumatic stress disorders are seen in civilian victims of terrorist attacks (NCRP 2001).

People exposed to invisible radiation contamination can fear that they have not gotten away from the threat to themselves or their children. Some people continue to live with the chronic fear and stress that they or their children will develop cancers or other health problems in the future (NCRP 2001). This is true even after a long time has passed

without negative health effects, the people are no longer living near the hazard area or the contaminated site was cleaned-up. The incident continues to be a powerful stressor on the victims (NCRP 2001).

The psychological effects following a terrorist RDD can be one of the most important problems to properly deal with. Psychological considerations will affect emergency responders and others near the contaminated site. Plans need to be developed that take into consideration those effects and ways identified to mitigate the psychological impact following a terrorist incident (FM 3-11.4 2003).

Large numbers of people can believe that they were affected following a terrorist attack involving invisible hazards. In the 1995 sarin nerve agent attack in Tokyo, twelve people died, but over 5,000 people sought treatment believing that they had been exposed (NCRP 2001). In Goiania, Brazil, over 112,000 people sought medical treatment (USACHPPM 1999). These large numbers of people seeking treatment and reassurance can overwhelm the local medical health system.

People in the US know about the devastating effects of the nuclear bombs. They have been told about the nuclear bombs that dropped on Hiroshima and Nagasaki at the end of World War II. People learned to fear a Soviet nuclear attack during the early years of the cold war, how to conduct duck-and-cover drills, and where the fallout shelters were so that they could run to them to try to survive a nuclear attack. More recently, they know about the nuclear accidents at Three Mile Island in the US and Chernobyl in the Soviet Union. People in the US have learned and have been conditioned to be afraid of nuclear radiation (NCRP 2001).

There are dramatic differences in the types of radiation, the intensity of the energy they have, and the physical short-term and long-term effects that they can have on individuals. The psychological effects of nuclear radiation and contamination are not necessarily linked or proportional to these physical variables (FM 3-11.4 2003). Psychological effects are tied more closely to a timely understanding of the actual risks of radiation exposure. People can begin to deal with an event and to determine follow-on actions once they understand the real danger posed by radiation.

Major Nuclear Accidents and Incidents

There have been many nuclear and radiological incidents in the last twenty years that have shaped peoples understanding and fear of radiation. Some of these events have been major accidents, like Chernobyl. Others have been smaller and have received less attention in the press. These smaller events, though less devastating, occurred more frequently and were not just limited to other countries. They occurred in the US as well. The incidents reinforced the understanding and belief that people have that a nuclear incident could happen near them.

The nuclear disaster at Chernobyl in the former Soviet Union on 26 April 1986 is one of the primary incidents that come to mind when people think about nuclear accidents. An explosion and fire occurred at one of the four nuclear reactors at the power plant during testing. The reactor was destroyed and radiation was released. The explosion was a major disaster and impacted the lives of an enormous number of people. The environmental effects in the surrounding area were immense, but the radiological fatalities were not as large as some might assume. Thirty-one people died including two workers who were killed in the initial explosion. Twenty-eight firefighters and

emergency clean-up workers died from the effects of high-radiation exposure during the first three months after the explosion and one person died of a heart attack (IAEA n.d.).

An exclusion zone with a radius of 30 kilometer was established around the plant. This forced 116,000 people to leave their homes and evacuate. It is estimated that fewer than 10 percent of the evacuees received a dose of 50 cGy and 5 percent received a dose of more than 100 cGy (IAEA n.d.).

About 200,000 clean-up workers, called “liquidators,” went to the accident site over the next year and worked to clean up the contamination and build a sarcophagus over the destroyed reactor to contain the radiation. These workers received an average dose of 100 cGy and about 10 percent of them received a dose near 250 cGy. A few personnel received doses in excess of 500 cGy (IAEA n.d.). There has not been a demonstrable increase in cancers or other adverse health effects among those workers even though the liquidators were exposed to the radiation (IAEA 2003c).

Many different radioactive elements were released into the environment when the reactor exploded. From a health perspective, radioactive iodine was one of the most immediate elements of concern for children. The primary ways people were exposed to radioactive iodine was from inhaling radioactive dust particles or ingesting milk and other foodstuffs that were contaminated with it.

In the body, radioactive iodine concentrates in the thyroid gland and irradiates the thyroid as long as it is there. This will cause an increase in cases of thyroid cancer (NCRP 1987). It usually takes at least four years before the cancer cases begin to present themselves.

Children under the age of fifteen at the time of the accident were the most susceptible to the effects of radioactive iodine on their thyroid glands. The cells in children's bodies grow and divide more rapidly than the cells found in adults. Radiation can damage these cells causing them to become cancerous. In the first fifteen years after the accident, there were at least 1,800 documented cases of thyroid cancer in children that were exposed to the radiation (IAEA 2003c). Fortunately, most of the cancers are successfully treated through surgery and medication.

One of the most profound effects of the disaster was the psychological impact that it had on the inhabitants of the region. There have been significant psychological effects among the people directly affected. Some of this may be due to the lack of information initially given to the public following the incident or the forced evacuations and relocations. The people were affected by the fear of serious health consequences that the radiation might have on them or their children.

Another example is the serious radiological incident that occurred in Goiania, Brazil, in September 1987. The radiological incident was second only to Chernobyl in the effect that it had on personnel and the environment. A radiotherapy machine was taken from an abandoned cancer clinic and taken apart. Inside the machine was a lead canister containing 1,400 curies of cesium-137 (USACHPPM 1999).

The radioactive material was in the form of a sparkling blue powder. Both children and adults handled the radioactive powder and rubbed it on their bodies while playing with it. They also shared it with other families and friends. One of the victims was a six-year-old girl. It is estimated that she "received five to six times the lethal dose of radiation for adults" (USACHPPM 1999).

After a week, some of the people began to feel the physical effects of the damage being done by the radiation and went to a medical clinic to seek treatment. The people had no way to know how dangerous the material was or that it was actually killing them while they played with it. The Brazilian government found that 244 people were contaminated and that 54 of them were serious enough to be hospitalized. Twenty people received doses between 100 to 800 rads (USACHPPM 1999). In the end, four people died as a direct result of the radiation exposure.

The radioactive material spread throughout the city contaminating homes, businesses, and the ground. Eighty-five homes were leveled during clean-up operations. Over 3,500 cubic meters of radioactive waste were removed and the local economy was devastated (IAEA 2002). Through assistance from the IAEA the government of Brazil was able to work to decontaminate the people and the parts of the city that were affected.

Another example of a radiological incident occurred in 1995 when authorities averted a terrorist attack using a RDD. Chechen rebels placed a RDD in a park in downtown Moscow, Russia. The rebels called a television station and told them that they had planted the dirty bomb in the park. When authorities went to the park, they found the RDD containing radioactive cesium. The device did not explode. Subsequently, the device was safely removed from the park. The incident made international news and acted as a reminder to the citizens of Moscow of the fear that many of them felt following the accident at Chernobyl.

Radiological Material Availability and Threat

The International Atomic Energy Agency (IAEA), a United Nation's Agency, has been working with the international community on the safety and security of high-risk

radioactive sources. The IAEA identified that high-risk radioactive sources are vulnerable to accidents, and there have been reports of illicit trafficking in radioactive materials. The IAEA has been working with member countries to respond to illegal use of radioactive material. One of the IAEA's primary concerns is for the safety and security of "orphaned" radioactive sources. "Orphaned" sources are radioactive sources that are currently not under regulatory control. They may never have been subject to regulation or they may have been regulated initially but were lost, stolen, or misplaced over a period of time (IAEA 2003a).

Radioactive sources can still be very powerful and cause great harm even after they are no longer able to do what they were initially manufactured to do and are taken out of use. The owner of the source has a financial interest in securing it as long as the radioactive source has commercial value. Once the source becomes just a liability, the owner may reduce the costly security precautions and the source will become more susceptible to loss (Ferguson 2003). The owner may also decide to wait to get rid of the source due to high disposal costs (Ferguson 2003). The longer the owner waits to properly dispose of the radioactive source the greater the likelihood of mishap.

In March 2003, the IAEA held the International Conference on the Security of Radioactive Sources in Vienna, Austria. Over 700 people from more than 120 countries participated. U.S. Secretary of Energy, Spencer Abraham, presided over the conference and the United States government and the government of the Russian Federation cosponsored the conference. The conference discussed ways to promote greater international cooperation to secure and control high-risk radioactive materials. The major findings of the conference were that:

(1) High-risk radioactive sources that are not under secure and regulated control, including so-called “orphan” sources, raise serious security and safety concerns. Therefore, an international initiative to facilitate the location, recovery and securing of such radioactive sources throughout the world should be launched under the IAEA’s aegis.

(2) Effective national infrastructures for the safe and secure management of vulnerable and dangerous radioactive sources are essential for ensuring the long-term security and control of such sources. In order to promote the establishment and maintenance of such infrastructures, States should make a concerted effort to follow the principles contained in the Code of Conduct on the Safety and Security of Radioactive Sources that is currently being revised ... as well as the security requirements in the BSS (Basic Safety Standards). In this context, the identification of roles and responsibilities of governments, licensees and international organizations is vital. Therefore, an international initiative to encourage and assist governments in their efforts to establish effective national infrastructures and to fulfill their responsibilities should be launched under the IAEA’s aegis, and the IAEA should promote broad adherence to the Code of Conduct once its revised version has been approved. (IAEA 2003a)

The IAEA conference identified several additional findings. They encouraged the development of national action plans to locate and recover high-risk radioactive sources. They also recommended that countries seek ways to improve long-term control over radioactive sources throughout the sources lifetime. Finally, the conference recommended that greater effort was needed to detect and interdict trafficking in high-risk radioactive sources and that countries develop comprehensive plans be developed to prepare for a radiological emergency (IAEA 2003a).

Speaking at the conference Secretary Abraham stated, “It is our critically important job to deny terrorists the radioactive sources they need to construct such RDD weapons” (IAEA 2003b). He went on to state, “Our governments must act to identify all the high-risk radioactive sources that are being used and have been abandoned. We must educate our officials and the general populace, raising awareness of the existence of these dangerous radioactive sources and the consequences of their misuse” (IAEA 2003b).

The Director General of the IAEA, Dr. Mohamed ElBaradei, spoke at the beginning of the conference. In his remarks he stated that: “Source security has taken a new urgency since 9/11” (IAEA 2003b). He also said, “There are millions of radiological sources used throughout the world. Most are very weak. What we are focusing on is preventing the theft or loss of control of the powerful radiological sources” (IAEA 2003b).

The IAEA believes that more than 100 countries may have inadequate radiological control programs and even countries that do have established programs have problems with lost or stolen sources (Gonzalez 1999). The US has arguably the most stringent control over its radioactive sources but every year the Nuclear Regulatory Commission (NRC) receives more than 300 reports of lost, stolen, or abandoned radioactive sources (IAEA 2003b). Other countries are much worse. The programs in some countries are so inadequate that they may not be even able to detect the theft of radioactive sources (IAEA 2003b).

The US government believes that the threat of nuclear and radiological terrorism is real. In 2002, Senator Domenici of New Mexico cosponsored a bill in the US Senate at sought to address the problem of loose radiological sources in foreign countries. The bill was entitled the “Nuclear and Radiological Terrorism Threat Reduction Act of 2002.” The bill was designed to create an international repository for radiological sources found in other countries. The intent of the legislation was to establish a way to safeguard radiological materials found in other countries, so that they could not find their way into the black market and threaten US interests. Congress made five findings in the bill:

1. It is feasible for terrorists to obtain and to disseminate radioactive material

using a radiological dispersal device (RDD), or by emplacing discrete radioactive sources in major public places.

2. It is not difficult for terrorists to improvise a nuclear explosive device of significant yield once they have acquired the fissile material, highly enriched uranium, or plutonium, to fuel the weapon.

3. An attack by terrorists using a radiological dispersal device, lumped radioactive sources, and improvised nuclear device (IND), or a stolen nuclear weapon is a plausible event.

4. Such an attack could cause catastrophic economic and social damage and could kill large numbers of Americans.

5. The first line of defense against both nuclear and radiological terrorism is preventing the acquisition of radioactive sources, special nuclear material, or nuclear weapons by terrorists (Domenici n.d.).

In 2002, the Federal Bureau of Investigation (FBI) arrested an American, Jose Padilla, on suspicion of planning to make and explode a RDD in the US. Mr. Padilla has ties to the Al Qaeda terrorist network and was arrested at Chicago's O'Hare Airport when he arrived. The FBI believes that he was on a reconnaissance mission in preparation for a RDD attack. As of this writing, two years after his arrest, Mr. Padilla remains in custody. The government is holding him as an enemy combatant.

In December 2003, the federal government was concerned about the threat of a dirty bomb being exploded in the US (Mintz and Schmidt 2004). The Department of Energy sent out teams of scientists to try to find the dirty bombs in at least five major cities. The primary concern was that a RDD attack might occur during New Year's Eve celebrations where there were large gatherings of people (Emanuel, Porteus, and Wright 2004). Other scientists remained ready to deploy on short notice if there was an attack. Those other scientist would provide additional consequence management assistance following the RDD attack.

Dr. Henry Kelly, President of the Federation of American Scientists, provided testimony on the threat of RDDs to the US Senate Committee on Foreign Relations on 6 March 2002. The primary findings of his organization are that:

1. Radiological attacks constitute a credible threat. Radioactive materials that could be used for such attacks are stored in thousands of facilities around the US, many of which may not be adequately protected against theft by determined terrorists. Some of this material could be easily dispersed in urban areas by using conventional explosives or by other methods.
2. While radiological attacks would result in some deaths, they would not result in the hundreds of thousands of fatalities that could be caused by a crude nuclear weapon. Attacks could contaminate large urban areas with radiation levels that exceed EPA health and toxic material guidelines.
3. Materials that could easily be lost or stolen from US research institutions and commercial sites could contaminate tens of city blocks at a level that would require prompt evacuation and create terror in large communities even if radiation casualties were low. Areas as large as tens of square miles could be contaminated at levels that exceed recommended civilian exposure limits. Since there are often no effective ways to decontaminate buildings that have been exposed at these levels, demolition may be the only practical solution. If such an event were to take place in a city like New York, it would result in losses of potentially trillions of dollars. (FAS 2002)

In his testimony, Dr. Kelly went on to discuss his concerns for the security of radiological devices in this country. He believes that businesses will do an adequate job of securing their radiological sources as long as the business has a financial interest in doing so. Businesses may become lax on securing the radioactive sources once the source is no longer needed or has aged to the point that it is not able to do what it was designed to do. The likelihood of abandonment or theft increases once the source has outlived its economic usefulness and becomes an economic burden.

Dr. Kelly provided several case studies to illustrate the potential devastating effects from a RDD. The following case studies are taken from his testimony. Numerous factors would affect the outcome of a RDD attack. The type, amount, and form of the

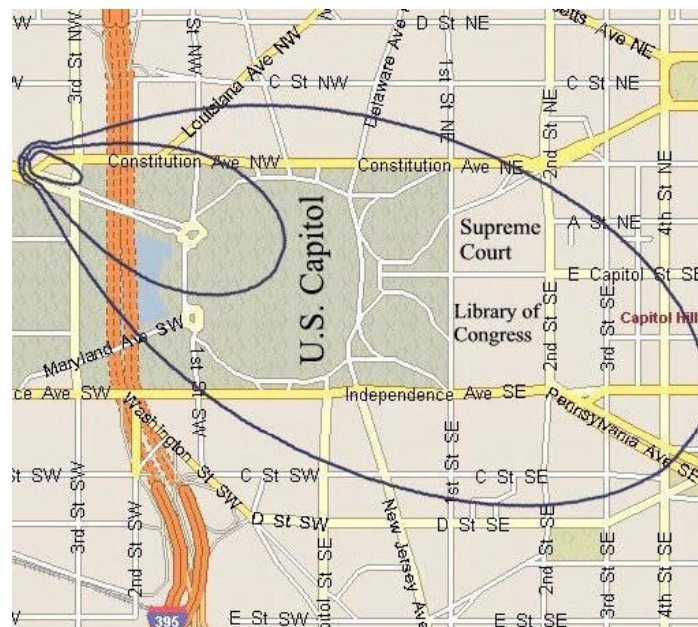
radiation source, the weather conditions, and the number and proximity of the RDD to buildings are all factors that affect a prediction (FAS 2002). An assumption was made that twenty percent of the radiological material would be small enough to be carried downwind in a cloud. This would allow it to be able to be inhaled. People would also be exposed to the radioactive dust that would fall to the ground. Dr. Kelly also stated that the case studies were illustrative in nature only but that he thought that they were accurate. He stated that they could be either too high by a factor of ten or too low by the same factor.

The Environmental Protection Agency (EPA) would provide recommendations to governmental officials following a RDD attack. People in the areas exceeding the EPA recommended radiation exposure limits would be evacuated. An attempt could then be made to decontaminate the effected area and reduce the radiation levels.

Urban radiological decontamination would be a monumental undertaking. Some of the radioactive materials can bind to concrete, soil, or asphalt creating a challenge to effective decontamination operations. That concrete or soil would have to be physically collected and removed as radioactive waste. The EPA would want the area to be decontaminated to the point that less than one person in ten thousand would die of cancer from the residual radiation. If this could not be done successfully then the EPA would probably recommend that the contaminated area be eventually abandoned (FAS 2002).

In the first case study provided by Dr. Kelly a medical gauge containing cesium is used in a RDD (see figure 3). This is the same type of medical device that was found in North Carolina two weeks before Dr. Kelly gave his Congressional testimony. In his example, ten pounds of TNT is used to explode the RDD in Washington D.C. The

radioactive cloud would not cause immediate health effects but would contaminate the downtown area. A five-block area would be contaminated enough so that one person per thousand would die of cancer if they decided to continue to live there and the area was not decontaminated to reduce the radiation levels. The outer ring shows the area that exceeds EPA contamination limits.



Inner Ring: One cancer death per 100 people due to remaining radiation
 Middle Ring: One cancer death per 1,000 people due to remaining radiation
 Outer Ring: One cancer death per 10,000 people due to remaining radiation

Figure 3. Long-Term Contamination Due to Cesium Bomb in Washington, DC

Source: FAS 2002.

The next example from Dr. Kelly shows what could happen if a radioactive cobalt source was used in a RDD in New York City. Food irradiation plants use cobalt sources. This type of attack is less probable than the previous example but was used by Dr. Kelly to discuss what could happen if a source were stolen. After the explosion, the radioactive

cloud would again not cause immediate health effects but a large area, one thousand kilometers, would be contaminated. If the area were not decontaminated, there would be an area of approximately 300 city blocks that would see an increased cancer risk of one in ten for people living in the area for forty years (see figure 4). There would be a one in one hundred chance of dying from cancer for people living in the entire borough of Manhattan.

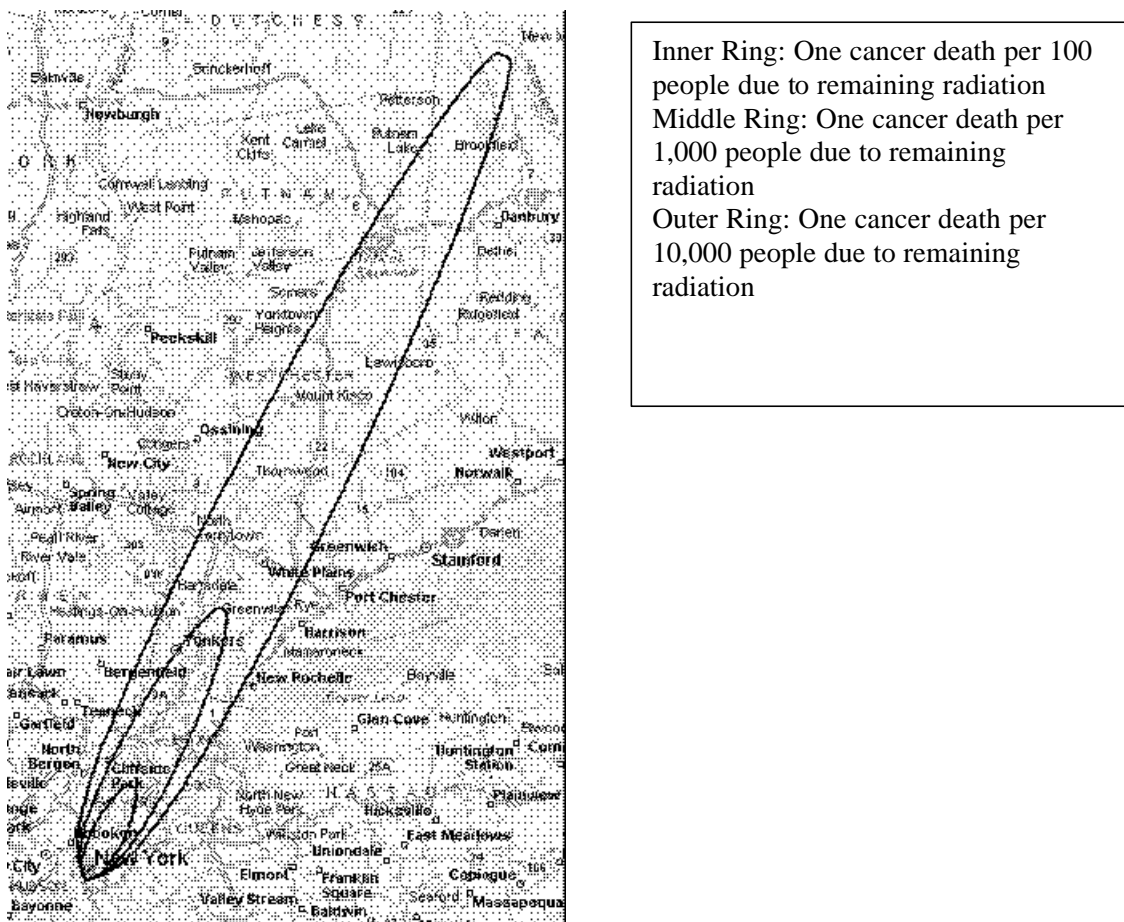


Figure 4. Long-term Contamination Due to Cobalt Bomb in NYC

Source: FAS 2002.

The Health Physics Society is a major scientific organization that encourages radiation research and safety focusing on the potential risks of radiation relative to the benefits. The society published a position statement for decision makers following a RDD attack entitled “*Guidance for Protective Actions Following a Radiological Terrorist Event*” (Health Physics Society 2004). The society believes that it is very unlikely that a RDD will pose an “immediate health hazard” (Health Physics Society 2004) and that the current federal safety standards should be adhered to. They did not advocate that there would be no health effects; only that it was unlikely to be an immediate health threat. The society provided recommendations for how to respond immediately after an incident, during an intermediate phase, and during the recovery and clean-up phase. Those recommendations included issues associated with sheltering in place, evacuation, decontamination, and allowable exposure rates.

Military Publications

One of the primary Joint military publication that provides information on radiological hazards is Joint Publication (JP) 3-11, *Joint Doctrine for Operations in a Nuclear, Biological, and Chemical (NBC) Environment*. JP 3-11 was last updated on 11 July 2000. This publication primarily focuses on general NBC operations but does include a six-page appendix on nuclear hazard considerations. This appendix provides a cursory overview of the primary effects from a nuclear explosion and includes the Radiation Exposure Status (RES) categories.

RES is a record of the amount of radiation that soldiers have previously received. The principle of radiation exposure control is to keep the exposure levels as low as reasonably achievable (ALARA). Commanders can factor the units RES into their

decision-making process and consider selecting the unit for a mission with the lowest radiation exposure history. The original RES levels were developed to address high levels of radiation exposure. These levels are only normally attained following a nuclear explosion (see table 3). The RES levels were not designed to take into consideration soldier's long-term health effects (Umeno 1999).

Table 3. Radiation Exposure Status Categories	
RES-0	The unit has not had radiation exposure
RES-1	The unit has been exposed to greater than 0 cGy but less than or equal to 75 cGy ¹
RES-2	The unit has been exposed to greater than 75 cGy but less than or equal to 125 cGy
RES-3	The unit has been exposed to greater than 125 cGy
Notes: ¹ Nuclear radiation exposure status (RES) guidelines specify units in centigray (cGy); however, the US Navy is required by the Code of Federal Regulations to conduct radiation monitoring in classic radiation units such as R, rad, or rem. 1 CGy = 1 rad.	

Source: FM 3-11.4 2003, D2.

The North Atlantic Treaty Organization (NATO) created additional categories of RES in NATO Standardization Agreement (STANAG) No. 2473, *Commanders Guide on Low Level Radiation (LLR) Exposure in Military Operations* (USACHPPM 2001). The STANAG divided RES1 into five subcategories. JP 3-11 incorporated this guidance (see table 4). Using these additional categories commanders are better able to understand how much radiation a unit has been exposed to during previous missions. There is a big difference between two units that are both RES-1 but one unit is RES -1A with 0.5 cGy and the other is RES-1E with 75 cGy.

Table 4. Low-Level Radiation Guidance For Military Operations Other Than War (MOOTW)		
Total Cumulative Dose (See Notes ^{1,2})	RES Category	Recommended Actions
0 to 0.05 cGy	0	None
0.05 to 0.5 cGy	1A	Record individual dose readings. Initiate periodic monitoring.
0.5 to 5 cGy	1B	Record individual dose readings. Continue monitoring. Initiate rad survey. Prioritize tasks. Establish dose control measures as part of operations.
5 to 10 cGy	1C	Record individual dose readings. Continue monitoring. Update survey. Continue dose control measures.
10 to 25 cGy	1D	Record individual dose readings. Continue monitoring. Continue dose control measures. Update survey. Execute priority tasks only. ³
25 to 75 cGy	1E	Record individual dose readings. Continue monitoring. Continue dose control measures. Update survey. Execute critical tasks only. ⁴
¹ The use of the measurement millisieverts (mSv) is preferred in all cases. However, military organizations normally only have the capability to measure cGy. If the ability to obtain measurements in mSv is not possible, US forces will use cGy. The USN is required by the code of Federal Regulations to conduct radiation monitoring in classic radiation units such as R, Rad, or REM. 1cGy = 1 rad. ² All doses should be kept as low as reasonably achievable. This will reduce individual risk as well as retain maximum operational flexibility for future employment of exposed persons. ³ Examples of priority tasks are those that avert danger to persons and prevent damage from spreading. ⁴ Examples of critical tasks are those that save lives.		
Source: FM 3-11.4 2003, D4.		

JP 1-02, *Department of Defense Dictionary of Military and Associated Terms*, last amended on 5 June 2003, is the standard for US military terminology and acronyms. JP 1-02 does not define the key terms RDD, LLR, DU, or ALARA in the definition section of the publication and RDD is the only one of the four that is included in the acronym section. The term “dirty bomb” is also not included in the definition section and the definition of RES is not current. RES uses the former definition including categories RES 0-3 and does not include the new subcategories RES 1A through 1E.

One of the foundational publications for Chemical officers is Army FM 3-4, *NBC Protection*. FM 3-4, updated in February 1996, has been the primary doctrinal publication used to train chemical officers on NBC protection issues. Chapter four of this FM discusses nuclear protection. This chapter focuses on protective measures available before, during, and after a nuclear attack. It does not discuss the protection required at lower doses of radiation and does not include the STANAG No. 2473 exposure guidance. This is consistent with other FMs written before 2000 when the concern about the effects of LLR began to receive more attention.

FM 3-11.4, *Multi-service Tactics, Techniques, and Procedures for Nuclear, Biological, and Chemical (NBC) Protection*, published in June 2003, replaced FM 3-4. FM 3-11.4 still contains a section on nuclear protection but adds a twelve-page appendix D, “Radiological Protection.” This is an important addition to this foundational manual for Army chemical officers.

Appendix D of FM 3-11.4 includes the RES-1 LLR Guidance to ensure that it supports and synchronizes with JP 3-11. It also includes sections on LLR characteristics, sources, hazard avoidance and protection considerations, and psychological casualties resulting from a LLR incident. Each of the sections are touched upon but not discussed in detail. Finally, Appendix D provides information on depleted uranium (DU). DU is just another LLR source, but it has been the topic of much discussion since the end of the Gulf War and was included as a subsection.

Another primary FM for chemical officers is FM 3-14, *Nuclear, Biological, and Chemical (NBC) Vulnerability Analysis*, updated 24 September 1998. This FM assists chemical officers in conducting NBC vulnerability analysis and provides information to

assist in planning NBC force protection measures. FM 3-14 includes information on all NBC threats. The three main chapters deal with intelligence preparation of the battlefield, vulnerability analysis, and vulnerability reduction measures. FM 3-14 includes less than one page of information on LLR and DU in each of the vulnerability analysis and vulnerability reduction measures chapters.

Finally, FM 3-14 does include table 5 that shows the biological effects of nuclear radiation. The table provides information on the expected medical effects from 0-8,000 cGy with the first dose range being from 0-70 cGy. This is appropriate when considering radiation exposures following a nuclear explosion, but not when concerned about the biological effects following a LLR incident.

Table 5. Biological Effects of Nuclear Radiation			
DOSE RANGE (cGy, FREE- IN-AIR)	INITIAL SYMPTOMS	PERFORMANCE MEASURE (MID RANGE FOR DOSE)	MEDICAL CARE/DISPOSITION
0-70	From 6-12 hrs: none to slight incidence of transient headache and nausea, vomiting in up to 5% of personnel in upper part of dose range.	Combat effective.	None; RTD
71-150	From 2-20 hrs: transient mild nausea and vomiting in 5-30% of personnel.	Combat effective.	None. RTD: no deaths anticipated.
151-300	From 2 hrs to 2 days: transient mild to moderate nausea and vomiting in 20-70%, mild to moderate fatigability and weakness in 25-60% of personnel.	DT: PD from 4 hrs until recovery. UT: PD from 6 hrs to 1 day, 6 weeks until recovery.	At 3-5 weeks: medical care for 10-50%. At low end of range, <5% deaths. At high end, death may occur in up to 10% ; survivors RTD.
301-500	From 2 hrs to 3 days; transient moderate nausea and vomiting in 50-90%; moderate fatigability in 50-90% at high end of range.	DT: PD from 3 hrs until death or recovery. UT: PD from 4 hrs to 2 days and from 2 weeks until death or recovery.	At 2-5 weeks: medical care for 20-60%. At low end of range, <10% deaths. At high end, death may occur for more than 50% ; survivors RTD.

Legend:

CI- Combat ineffective (<25% performance capable)

DT- Demanding task

PD- Performance degraded (25-75% performance)

UT- Undemanding task

RTD- Return to duty

Table 5 (Continued)			
DOSE RANGE (cGy, FREE- IN-AIR)	INITIAL SYMPTOMS	PERFORMANCE MEASURE (MID RANGE FOR DOSE)	MEDICAL CARE/DISPOSITION
501-800	Within first hr: moderate to severe nausea, vomiting, fatigability and weakness in 80-100% of personnel.	DT: PD from 1 hr to 3 weeks ; CI from 3 weeks until death. UT: PD from 2 hrs to 2 days and from 7 days to 4 weeks ; CI from 4 weeks until death	At 10 days to 5 weeks: medical care for 50-100%. At low end of range, death may occur for more than 50% at 6 weeks. At high end, death may occur for 90% at 3-5 weeks.
801-3,000	Within first 3 minutes; severe nausea, vomiting, fatigability, weakness, dizziness and disorientation; moderate to severe fluid imbalance and headache.	DT: PD from 45 minutes to 3 hrs ; CI from 3 hrs until death. UT: PD from 1-7 hrs; CI from 7 hrs to 1 day; PD from 1-4 days ; CI from 4 days until death.	Medical care from 3 minutes until death. 1,000 cGy: 100% deaths at 2-3 weeks. 3,000 cGy: 100% deaths at 5-10 days.
3,001-8,000	Within the first 3 minutes: severe nausea, vomiting, fatigability, weakness, dizziness, disorientation, fluid imbalance, headache and collapse	DT: CI from 3-35 minutes; PD from 35-70 minutes ; CI from 70 minutes until death. UT: CI from 3-20 minutes; PD from 20-80 minutes ; CI from 80 min until death.	Medical care from 3 minutes until death. 4,500 cGy: 100% deaths at 2-3 days.
>8,000	Within the first 3 minutes: severe and prolonged nausea, vomiting, fatigability, weakness, dizziness, disorientation, fluid imbalance, headache, and collapse.	DT and UT: CI from 3 minutes until death.	Medical care needed immediately. 8,000 cGy: 100% deaths at 1 day.

Legend:

CI- Combat ineffective (<25% performance capable)

DT- Demanding task

PD- Performance degraded (25-75% performance)

UT- Undemanding task

RTD- Return to duty

Source: FM 3-14 1998, F5-F6.

CHAPTER 3

RESEARCH METHODOLOGY

This thesis uses a series of questions to build upon each other to answer the main question: Are United States Army chemical officers adequately trained to respond to a low-level radiation threat? In order to determine the answer to that primary question this thesis will answer some subordinate questions. The first subordinate question is: what is so dangerous about LLR? Secondly, how readily available is LLR material? Thirdly, What is the threat of the use of LLR material in the United States? Fourthly, what radiological training does Army chemical officers receive as lieutenants and captains? This thesis will analyze the literature and answer the primary question once these subordinate questions have been addressed.

The primary methodology for answering those subordinate questions was a literature review of experts in the field and a compilation and analysis of their works. A secondary method for answering the questions was to conduct personal interviews with subject matter experts in the fields of radiation safety and training. A combination of these two methods allowed for a comprehensive understanding of the current thinking of experts in the various aspects of this study.

The first subordinate question that this thesis considers is: What is so dangerous about LLR? How does it affect people and what is the danger of both short-term and long-term exposure. This question looks at the affects of radiation on people from both a physical and psychological perspective. In order to answer that question this thesis conducted an extensive review of academic and governmental literature on the subject.

Most universities have classes and publications on general chemistry and physics that provided the answers on the basics of radiation theory. Information from governmental agencies like the Federal Emergency Management Agency, the Environmental Protection Agency, and the Department of Homeland Security was also used in answering this question. These organizations play an important role in providing information and protecting the general public and have a wealth of knowledge on radiation safety and its effects. A large volume of research has been published on the medical effects of ionizing radiation. Much of this information is focused on large exposures similar to those that occurred in Hiroshima, Japan or Chernobyl, U.S.S.R. but there is adequate information on the effects of radiation at much lower levels. This information is incorporated into chapter two.

The second and third subordinate questions are how readily available is LLR material and what is the threat of the use of LLR material in the United States? These questions are answered in chapter two. Again, a literature review was conducted to understand how prevalent radiological sources are in the United States and how easy it would be for someone to acquire a radiological dispersal device that wanted to either threaten or actually explode such a device.

The fourth subordinate question is what radiological training does Army chemical lieutenants and captains receive? The U.S. Army Chemical School's Programs of Instruction (POI) for the CBOLC and the CMC3 were reviewed. The POI states the title of each class, the length of time given to teach it, and the terminal learning objectives (TLOs) for the class. The TLOs tell the reader what the student should have learned from the class. The TLOs also say what format the class will occur in. For example, will the

class be a conference lecture or a practical exercise. The radiological portions of the POIs are included in this thesis as Appendix 1 and 2. A discussion of the content of the training is found in chapter two and it is analyzed in chapter four.

In addition to receiving the POIs to answer the fourth subordinate question, the faculty and instructors for the radiation training courses of the U.S. Army Chemical School's Radiation Laboratories were interviewed. This provided additional information to help understand what is currently being taught and what classes are being developed for possible inclusion in the CBOLC and CMC3 courses in the future.

CHAPTER 4

ANALYSIS

Biological and Psychological Effects of Radiation

Radiation exposure can cause biological effects in humans at large doses but below an acute dose of 10 rem there has not been a scientifically proven correlation between radiation exposure and an increased cancer rate (Health Physics Society 2001). Adverse health effects have also not been corroborated for small chronic doses of radiation. The Health Physics Society believes that the “effects from low doses are either too small to be observed or are non-existent” (2001).

It is possible for soldiers to be exposed to radiation greater than 10 rem during military operations. Depending on the dose received, the soldier may begin to present symptoms of radiation sickness or they may be initially asymptomatic. Soldiers exposed to radiation greater than 10 rem will have an increased chance of developing cancer or have other adverse health effects later on in life.

Commanders need to consider the soldier’s previous radiation exposure and the estimated future exposure when assigning missions. Commanders have to balance the mission requirements and the ALARA principle in this decision making process. This will help them to achieve the mission and also take prudent measures to take care of the soldiers and not unnecessarily expose them to radiation.

Tables 5 in chapter two, taken from FM 3-14, show that soldiers receiving up to 150 cGy would continue to be combat effective and not need medical care (2003). Army NBC manuals that are used to teach chemical lieutenants and captains do not address the

issue of long-term medical effects on soldiers. Only the immediate medical effects of the radiation exposure are identified as issues of concern.

The fear of radiation exposure from a real or perceived threat can produce dramatic psychological effects that can effect military operations. The psychological impact of a RDD on a military unit could rival the effects of a nuclear detonation. Soldiers may not know the level of radiation that they have been exposed to, where it is safe to go to get away from the radiation, or how the radiation will effect them. This lack of information and fear of the unknown can produce acute stress and anxiety in soldiers.

Some soldiers may experience psychosomatic effects following a radiological incident. Under extreme duress, nausea and vomiting are common. Fear and tension in the unit may arise when a few soldiers start demonstrating symptoms of radiation sickness.

The psychological effects of a RDD may be as serious as the actual physical health effects. In world war two, for example, psychological casualties were the “largest single cause of lost military strength in that war” (FM 3-11.4 2003). Chemical officers need to be trained to expect this reaction in people so that they can be prepared to properly respond with accurate and timely information.

LLR Threat Assessment

The Army uses the military decision making process (MDMP) to help decide the best way to accomplish a mission. MDMP is a way to make sure that the plan we develop is feasible, acceptable, and suitable. The first step following receipt of the mission is to conduct a mission analysis. In a mission analysis the enemy threat is one of the most important considerations. What are the enemy’s capabilities? What is his most likely and

most dangerous course of action? Once we have a full understanding of the threat and our own capabilities and limitations, we can then develop a course of action to achieve our objectives while at the same time trying to inhibit the enemy from achieving his objectives.

The Soviet nuclear threat dominated U.S. doctrinal development and training for over fifty years. The threat of nuclear war was real and chemical officers were trained to be able to respond to a nuclear attack and properly advise their commanders. This helped the Army meet its strategic and operational objectives. The consequences of a nuclear attack were so much greater than a LLR incident that LLR was not considered a threat at any level: tactical, operational, or strategic. LLR on the battlefield would not prohibit the Army from achieving its objectives.

An examination of the threat of LLR shows that military units are likely to encounter LLR during future operations (FM 3-14 1998). Army units may be called upon to respond and provide assistance following a RDD attack or they may find a radioactive source in the area that they are operating in. Both possibilities require that chemical officers are trained to be able to appropriately advise their commanders.

To understand the threat of LLR on military operations we need to look at the availability of radiological sources, the ability of the radioactive material to cause injury or contamination, and the difficulty of making a radiological device. In the 2003 conference, the IAEA found that there is a legitimate safety and security threat for high-level radioactive sources (IAEA 2003a).

The threat of a RDD attack forces a reexamination of the tasks taught to lieutenants and captains during BOLC and CMC3. LLR is a potential condition of the

battlefield that units may have to face and chemical officers has to be ready to respond. The only way that they will be ready is if the Chemical School trains them.

Military Manuals and Training

Joint publications and field manuals provide a doctrinal foundation for military operations and training. The military manuals published since 2000 have begun to add some LLR information but the process is far from complete. Including and improving the amount of LLR information in doctrinal manuals is the first step in the process of educating chemical officers about the hazards of LLR and the ways to mitigate those risks. LLR information can be taught in the BOLC and CMC3 courses once it is incorporated into the doctrinal manuals.

JP 3-11, *Joint Doctrine for Operations in a Nuclear, Biological, and Chemical (NBC) Environment*, last updated in July 2000, does not provide much information on LLR other than the table showing RES levels 1A-1E (see table 4). This table standardizes US doctrine with NATO and STANAG #2473. The radiological information that is in JP 3-11 discusses nuclear weapons effects and not LLR. The manual simply states that terrorists can use dispersal devices as a means of attack and that avoidance may be the most effective protective measure when dealing with industrial radiation hazard areas. JP 3-11 needs to add sections that discuss the threat of RDDs and LLR, the actions required to minimize the effects, and the battlefield implications.

JP 1-02, *Department of Defense Dictionary of Military and Associated Terms*, last revised in June 2003, needs to be updated with military terms related to radiation. The acronym ALARA is the most glaring example of a term that should have already been included. The ALARA principle is probably found in every textbook related to radiation

and health effects. It is a guiding principle not just for LLR but for operations on a nuclear battlefield as well. The acronyms DU, LLR, and RDD and the term “dirty bomb” are common radiological terms and should be defined in the military dictionary. There has been a lot of discussion about depleted uranium, DU, since the end of the Gulf War in Iraq. It is surprising that this term and its acronym have not been included in the dictionary. Finally, the definition of RES uses the former categories, RES 0, 1, 2, and 3, and has not been updated to include the subcategories RES 1A through 1E.

FM 3-11.4, *Multi-service tactics, techniques, and procedures for nuclear, biological, and chemical (NBC) protection*, published in June 2003, is a vast improvement over FM 3-4, NBC Protection, on the subject of LLR. The FM includes the LLR guidance for RES 1A-1E as found in JP 3-11 but also goes much further. A weakness of the FM is that it places information on LLR and DU in separate sections of appendix D. DU is a specific type of LLR source and should be a subcategory of the section on LLR. Having the section on DU separate from LLR implies that the two are different and indicates a possible lack of understanding on the part of the manual writers.

FM 3-14, *Nuclear, Biological, and Chemical (NBC) Vulnerability Analysis*, published in 1998, incorporates the nuclear vulnerability information that is found in FM 3-3-1, *Nuclear Contamination Avoidance*. FM 3-3-1 was published in 1994 and has not been updated since. Table 5, the biological effects of nuclear radiation, was taken directly from FM 3-3-1 and incorporated into FM 3-14.

The dose range for the RES levels changed between 1994 and 1998. In 1994, when FM 3-3-1 was published, RES 1 was 0-70cGy, RES 2 was 71-150 cGy, and RES 3 was more than 150 cGy. The biological effects categories found in FM 3-3-1, table 5 of

this thesis, conform to those RES levels. The RES levels were later modified to conform to NATO standards. RES 1 is now 75 cGy or less, RES 2 is 125 cGy or less, and RES 3 is greater than 125 cGy (see table 3 in chapter two). The biological effects table in FM 3-14, however, was not revised to conform to the new RES levels.

FM 3-3-1 has not been updated to include the new RES levels or the corresponding new categories for the biological effects tables. This discrepancy can create problems and must be corrected. In the summer of 2003, reserve CMC3 instructors were given a CD containing all of the CMC3 classes. The radiological class contained slides with the old RES levels.

Chemical Basic Officer Leadership Course POI

Second lieutenants attend the CBOLC shortly after commissioning. All lieutenants attend common core training and then receive phase II specialized training based on their military branch. Chemical lieutenants receive thirteen weeks and one day of specific chemical branch training. The current CBOLC POI, information on each class in the course, was implemented in 2002.

The radiological portion of the CBOLC POI (see appendix A) contains sixty-one hours of instruction, practical exercise, and examination. There are twenty different classes each with their own terminal learning objectives (TLOs). TLOs are the tasks that the course author expects the student to have completed or learned in that class. The focus of the CBOLC radiation instruction is to prepare chemical lieutenants to conduct battalion-level staff operations in a nuclear environment. The focus is clearly on nuclear warfare operations and not on low-level radiological hazards that are not significant enough to impact current military operations. The training provides an overview of the

fundamentals and does not go into too much depth on any one subject. The CBOLC radiation portion of the POI contains only four hours of instruction that would be considered exclusively LLR focused.

The CBOLC radiation training begins by spending a short time, three hours, on the fundamentals and basics of nuclear radiation and operations. The first class begins by explaining the role that chemical officers play in their unit during nuclear operations. It then proceeds into a discussion of the fundamentals of radiation.

The course looks at defensive nuclear considerations. It focuses on protective measures to reduce a unit's vulnerability to the effects of a nuclear detonation. The course teaches chemical officers what to do following a nuclear detonation including submitting NBC nuclear reports, predicting hazard areas from fallout, and advising the commander on operational exposure guidance.

The course teaches students how to use two company-level radiation detection devices, the VDR-2 and the UDR-13, and conduct radiological monitoring and survey operations. The VDR-2 can detect beta radiation, identifying that it is there but not the amount. Both the VDR-2 and the UDR-13 can detect and measure the amount of gamma rays. These two types of radiation are of most concern in military operations following a nuclear detonation. The VDR-2 and the UDR-13 cannot detect alpha radiation and chemical lieutenants are not trained with another piece of equipment to detect it.

The CBOLC radiation training then teaches what to do to protect soldiers from the effects of radiation. It teaches chemical officers about nuclear fallout, where it will occur, when it will arrive, and how it will affect unit operations. The course also discusses the operational aspects of neutron-induced radiation contamination following a

nuclear explosion. Finally, the students learn about radiological decontamination operations and how to reduce the hazard once contaminated.

CBOLC provides four hours of awareness training on depleted uranium (DU). This includes three hours of lecture and a one-hour film. DU is an example of a LLR material that would be present on the battlefield. The class discusses what DU is, the hazard it presents, and what steps to take to protect one's self from exposure to it. This is the only class specifically focused on LLR on the battlefield.

The CBOLC radiation POI does not contain some important TLOs. The course should include information on the threat an RDD poses and other potential LLR sources that soldiers may encounter on the battlefield. A RDD attack is a plausible event, which is drastically different from a nuclear detonation. The ramifications of a RDD need to be addressed. The other radiological sources that may be found on the battlefield include both civilian equipment and foreign military equipment that contain radioactive sources.

The CBOLC POI does not have a separate TLO on either the physical or psychological effects of radiation. Some information on these effects are worked into classes as enabling learning objectives but knowing the physical or psychological effects are not TLOs. The psychological effects of a RDD or other LLR source could dramatically impact military operations and need to be emphasized.

CBOLC does not have a separate class on radiation quantities and units. The subject is worked into other material. Radiation quantities and units can be very confusing and are not commonly used. The radiation detectors also automatically switch what units they are reporting in depending upon the level of radiation they are picking up.

Failure to be attentive to the unit of measure that the detector is reading in can drastically change the significance of the reading.

Finally, the CBOLC POI should have TLOs discussing what subject matter experts are available to help chemical officers deal with radiological incidents, what resources are available, and what staff coordination would be required. Some of these subject matter experts include preventive medicine officers, nuclear science officers, and unit safety civilians. Some of these individuals will have a wealth of knowledge and training on radiation safety issues and can be of enormous assistance if the chemical officer knows to ask for it. Reach-back capabilities can provide a link to scientists and other full time radiation experts in the US. Reach-back capabilities can also provide digital resources to help the chemical officer properly handle and document the situation. Staff coordination for a radiological event would most likely include all of the primary battalion staff officers plus other sections like information operations, civil affairs, psychological operations, and medical.

CMC3 POI

Chemical captains receive one hundred and one-half hours of radiation training in the CMC3 POI (see appendix B). The current POI has been in use since 1999. The radiation portion of the POI is broken into two distinct sections. Section 1 is a forty-two hour block of instruction on operational radiation safety. In general, this is additional information not found in CBOLC. Section 2 is a 58 1/2 hour block of instruction on tactical nuclear operations. This training is focused on nuclear weapons and operations similar to CBOLC but goes into greater depth and adds additional TLOs. Combined, this

course provides an additional week of radiation training for CMC3 students that CBOLC students do not receive.

Many of the CMC3 class titles are the same as the CBOLC classes. The CMC3 classes are generally a short review of the material covered during CBOLC followed by a more in-depth study of the subject. There are also many additional area not covered during CBOLC.

The operational radiation safety portion of the CMC3 course is a vast improvement over what is taught in CBOLC with many additional TLOs. It also provides information more directly applicable to LLR operations. This training provides the captains the awareness training needed to be local radiation protection officers in follow-on assignments.

The course begins by going much further in depth into the radiation fundamentals and discusses radiation quantities and units. This is foundational to the two-hour block of instruction on the biological effects of radiation. Neither of these topics were TLOs in CBOLC.

The course also adds instruction in the capabilities and operation of the AN/PDR-77 radiation set. The AN/PDR-77 set includes the AN/VDR-2 radiac meter that CBOLC students are taught how to use. The AN/PDR-77 also includes additional meters that measure alpha radiation and x-rays. Thus, chemical captains are taught how to detect the four types of radiation whereas chemical lieutenants are only taught how to detect beta radiation and gamma rays.

The classes on the capabilities and limitations of the various radiation detectors are very important. Chemical officers do not train with the radiac meters often and it is

easy to forget what the equipment can actually detect or the accuracy of the piece of equipment. A good example is the DT-236 radiac detector. The DT-236 is an individual detector that measures neutron and gamma rays from 0-999 cGy. The DT-236 detector would not be an appropriate detector to use if the soldier was in a LLR area that was reading in the mrem per hour range.

The operational radiation safety instruction discusses many areas not found in CBOLC and looks at radioactive materials from an environmental perspective. There are TLOs on regulatory guidance, standards for protection, and proper handling, control, storage, transportation, and disposal of radioactive sources. There is also a class on managing radiation accidents. In general, all of these TLOs are focused on and applicable to LLR sources.

The CMC3 depleted uranium class provides more than just the awareness level training that students received in CBOLC. The class provides operational level information and information on battle damage assessment and repair concerns of vehicles. In CBOLC, the TLO on depleted uranium was the only class focusing on LLR. This is certainly not the case in CMC3.

The tactical operational radiation section of the course reviews much of the material found in CBOLC but does add several new TLOs and provides more information on the previously taught subjects. The nuclear weapons effects class focuses more on how it relates to the intelligence preparation of the battlefield process. Procedures to warn friendly units of an impending nuclear blast, STRIKEWARN messages, are taught. Finally, this section includes an eight-hour tactical radiological exercise that incorporates many of the TLOs that the students have just completed.

The CMC3 POI should include TLOs addressing the RDD threat and the psychological effects of radiation exposure. Chemical captains, like the lieutenants, should be conversant in these critical tasks. The psychological effects can quickly degrade troop morale and distract soldiers from mission accomplishment at a critical time. Psychologically traumatized soldiers that believe they were exposed to radiation can begin to display physical symptoms consistent with radiation exposure even though they were not physically affected.

Other TLOs need to be included in the CMC3 POI. The captains need to be given awareness training on the potential civilian and foreign military radiological sources that they might encounter on the battlefield. The course also needs to teach the captains where they can turn to for additional assistance. What are the reach-back capabilities? Who are subject matter experts that can help them? Are there nuclear science, preventive medicine, or unit safety officers that have the training and experience to be of assistance? Which other staff sections do they have to coordinate with to properly handle a radiological incident? Who else needs to know?

The CMC3 POI includes a tactical radiological exercise near the end of the radiological section. This is a good opportunity to integrate and demonstrate proficiency in the TLOs. Many of the LLR TLOs could be integrated into this exercise. Captains would be able to advise their commanders on LLR issues, as well as the nuclear weapons employment and effects issues.

CHAPTER 5

FINDINGS AND RECOMMENDATIONS

Biological and Psychological Effects of Radiation

Acute low-level radiation exposure greater than 10 rem will cause an increase in adverse health effects for the exposed individuals (US NRC 2003). Above 10 rem only priority tasks that “avert danger to persons and prevent damage from spreading” (US Joint Chiefs of Staff 2000) should be executed. Harmful effects from acute radiation exposure below 10 rem have not been clinically demonstrated.

The ALARA principle should be adhered to in all military operations regardless of the amount of radiation expected or actually exposed to. This is true even though the scientific community cannot provide evidence for biological effects from radiation exposure below the 10 rem level. Chronic LLR exposure should be limited to the greatest extent possible. By adhering to the ALARA principle commanders are able to balance the mission requirements with the long-term potential health consequences that soldiers face.

Psychological effects and consequences from low-level radiation exposure can be more severe than the biological effects (NRC 2001). The fear of the unknown or misunderstood can be worse than the fear of the known. Following a radiological incident, people who were exposed may become very afraid. It is easy for a person to believe the worst and worry that the radiation will cause cancer or some other health problem. The exposed victims may have a chronic fear that they or their children will develop cancer or other health problems and die from the radiation. This fear of the

affects of radiation can produce an elevated level of stress on the individuals that stays with them for many years.

Psychological effects are not limited to only those individuals who were physically exposed. People may become psychologically affected even though they were not near the radiation site or source. Radiation is invisible and cannot be detected using a person's five senses. This can allow the person to question if they might have been affected.

Timely information and education are some of the keys to limiting psychological effects following a radiological incident. Recognized scientific authorities or people in authority need to quickly disseminate information on what has happened and what is being done to limit the radiological effects. People will begin to feel reassured and more psychologically stable after they hear from those authority figures and begin to internalize the information.

LLR Threat

Radiological sources are abundant in the world and soldiers can expect to encounter them while conducting military operations. FM 3-14 states, "There exists, in all operations, the possibility of a low-level radiation threat" (1998). Most sources are low-level and will not cause either immediate effects or a discernable increase in adverse health risk in the future. Soldiers can also encounter high-level radiological sources that were either lost or stolen.

The International Atomic Energy Agency believes that "high-risk radioactive sources . . . raise serious security and safety concerns" (IAEA 2003a) and that more than 100 countries may not have adequate radiological controls. U.S. Secretary of Energy

Abraham agreed with these findings. The problem is primarily with those “orphan” radioactive sources not under regulatory control. Even the US is not immune to the problem of adequate controls on their radiological sources since every year the NRC receives more than 300 reports of lost, stolen, or abandoned radioactive sources (IAEA 2003b).

A RDD is a credible event both in the United States and overseas. Terrorists could acquire radioactive material, make, and then detonate a dirty bomb. This would have a potentially enormous economic and psychological effect on a large number of people. The physical effects would be more limited but could still be a major concern.

Military Publications

Joint and Army publications have begun to integrate low-level radiation information into their manuals. Additional work must be done. The following is a list of publications that need to be updated and the major area of weakness of it.

JP 3-11: Add LLR effects and impacts to military operations.

JP 1-02: Add the definitions of a dirty bomb, RDD, LLR, DU, ALARA, and the correct definition of RES 1A through 1E. Add the acronyms LLR, DU, and ALARA.

FM 3-3-1: Revise or update the RES categories and the biological effects tables to correspond to STANAG 2473, JP 3-11, and FM 3-14.

FM 3-11.4: DU should be shown as a subset of LLR and not separate.

FM 3-14: The biological effects of ionizing radiation table should be revised to show the radiation effects based on the current RES levels. A correlation to the cancer rate could also be included.

CBOLC and CMC3

CBOLC students do not receive adequate low-level radiological training. The training hours allotted in the POI focus on nuclear weapons and their effects. This is understandable since the consequences of a nuclear detonation are so much more severe than for a LLR event. An argument could be made that if chemical officers can properly advise their commanders on nuclear weapons issues then they can also advise them on LLR issues. The difference is that the level of risk and actions a commander is willing to take will be very different depending upon if his unit is on a nuclear battlefield or responding to a LLR incident. A commander will most likely require much lower radiation exposure standards when responding to a LLR incident.

Low-level radiation information should be integrated into the existing classes to the greatest extent possible. Additional TLOs should be added for key subjects but the time allotted could be shifted from some existing classes. This will make it more feasible for the LLR material to be included in the POI.

Chemical lieutenants need to be trained on several additional critical tasks to be able to properly advise their future commanders on LLR issues. The RDD threat and the biological and psychological effects of radiation exposure need to be TLOs. Awareness information on potential LLR sources on the battlefield, civilian and foreign military, also needs to be taught. Finally, chemical lieutenants need to be trained on the reach-back capabilities that are available, the other radiation subject matter experts available, and what staff coordination might be required to successfully advise their commander and resolve the situation.

CMC3 students receive much more low-level radiation training than the chemical lieutenants do but should receive additional LLR training. The operational radiation section is an appropriate place to integrate many of the needed TLOs. Some additional classroom time can come by shrinking the amount of time that CMC3 students spend on the nuclear weapons TLOs that they trained on as lieutenants in CBOLC. This is a review for them since they already received the nuclear weapons training. Web-based distance learning or a refresher training CD on nuclear weapons could also be made available. This would allow chemical officers to maintain their proficiency or relearn the training objectives before attending CMC3.

Chemical captains in CMC3 need training on several additional TLOs to be able to properly advise their future commanders on LLR issues. The additional TLOs are the same as needed in CBOLC with the exception of the biological effects of ionizing radiation TLO that is already included in the POI. The additional TLOs include: the RDD threat; the physical and psychological effects of radiation exposure; potential civilian and foreign military LLR sources on the battlefield; available reach-back capabilities; other radiation subject matter experts available to help resolve the situation like preventive medicine, nuclear science officers, and unit safety officers; and the staff coordination required to resolve the LLR incident.

Finally, low-level radiological situations need to be integrated into the end of section exercise. This will demonstrate that the students understand the various nuances of dealing with LLR issues and can properly advise their commander on how to respond. This eight hour tactical radiological exercise is already in the POI so additional time would not be required.

APPENDIX A

BOLC PHASE 2 CHEMICAL RADIATION TRAINING

COURSE: BOLC PHASE 2 CHEMICAL PHASE: 2 VER: 2
PREPARATION DATE: 2002/04/16
COURSE TITLE: CHEMICAL OFFICER LEADER COURSE PHASE II

*** ACADEMIC HOURS ***
PEACETIME MOBILIZATION
HOURS TYPE HOURS TYPE

PFN NO: OB-B035N 1.0 C 1.0 C
CLEARANCE: UNCLASSIFIED
TITLE: INTRODUCTION TO BATTALION OPERATIONS IN
A NUCLEAR ENVIRONMENT
TLO: Explain and define the role of the
Chemical officer from the Corps level to
unit level and their role in nuclear
defense within a battalion in a
classroom environment given FM 3-101 and
IAW with FM 3-101.

PFN NO: OB-B036N 1.0 C 1.0 C
CLEARANCE: UNCLASSIFIED 1.0 PE2 1.0 PE2
TITLE: RADIATION FUNDAMENTALS
TLO: Apply radiation fundamental tasks in a
classroom environment given FM 3-3-1 and
SH 3-95 with a minimum of 70% accuracy
on a written examination.

PFN NO: OB-B037N 3.0 C 3.0 C
CLEARANCE: UNCLASSIFIED 1.0 PE2 1.0 PE2
TITLE: DEFENSIVE MEASURES AGAINST NUCLEAR
WEAPONS EFFECTS
TLO: Identify and apply defensive measures
against effects of nuclear weapons in a
classroom environment given FM 101-31-1
with a minimum of 70% accuracy on a
written examination.

PFN NO: OB-B038N 1.0 C 1.0 C
CLEARANCE: UNCLASSIFIED 2.0 PE2 2.0 PE2
TITLE: NUCLEAR VULNERABILITY ANALYSIS
TLO: Conduct nuclear vulnerability analysis
in a classroom environment given threat
nuclear yield, disposition of friendly
troop units, analysis materials,
Commander's directives, Student
Handouts, FM 3-3-1, FM 3-4, and FM 3-14
with a minimum of 70% accuracy on a
written examination.

COURSE: BOLC PHASE 2 CHEMICAL PHASE: 2 VER: 2

*** ACADEMIC HOURS ***

PEACETIME MOBILIZATION

HOURS TYPE HOURS TYPE

PFN NO: OB-B039N 2.0 C 2.0 C
CLEARANCE: UNCLASSIFIED 2.0 PE2 2.0 PE2
TITLE: NUCLEAR BURST INFORMATION
TLO: Prepare and submit and NBC 1 and 2
Nuclear Report, describing the (NBCWRS)
NBC Warning and Reporting System in a
classroom environment given nuclear
attack data, FM 3-3-1, SH 3-95, SH
3-149, and GTA 3-6-8 IAW guidelines in
FM 3-3-1 and GTA 3-6-8.

PFN NO: OB-B040N 1.0 C 1.0 C
CLEARANCE: UNCLASSIFIED 1.0 PE2 1.0 PE2
TITLE: OPERATIONAL EXPOSURE GUIDANCE
TLO: Advise the Commander/Staff on the
Operational Exposure Guidance (OEG) in a
classroom environment given radiation
exposure data reports from units,
radiation dose status charts, and FM
3-3-1 IAW FM 3-3-1.

PFN NO: OB-B041N 4.0 C 4.0 C
CLEARANCE: UNCLASSIFIED 4.0 PE3 4.0 PE3
TITLE: FALLOUT PREDICTIONS
TLO: Prepare a simplified fallout prediction
and plot an NBC 3 Nuclear Report in a
classroom environment given nuclear
burst information, current effective
downwind message (EDM), an M52A2
Predictor, Rad Accessory Packet, overlay
paper, NBC 3 Nuclear Report, and FM
3-3-1 within 2mm of distance and
angles and azimuths are within 2
degrees and marginal information is
annotated IAW FM 3-3-1, Chapter 3.

PFN NO: OB-B042N 3.0 E3 3.0 E3
CLEARANCE: UNCLASSIFIED
TITLE: RADIOLOGICAL EXAM I
TLO: Take written exam on POI Files OB-B035N
through OB-B041N in a classroom
environment with a minimum of 70%
accuracy.

COURSE: BOLC PHASE 2 CHEMICAL PHASE: 2 VER: 2

*** ACADEMIC HOURS ***

PEACETIME MOBILIZATION

HOURS TYPE HOURS TYPE

PFN NO: OB-B043N 1.0 OTH 1.0 OTH

CLEARANCE: UNCLASSIFIED

TITLE: RADIOLOGICAL EXAM I CRITIQUE

TLO: Give feedback on POI files OB-B035N
through OB-B041N in a classroom
environment explaining reclama and exam
problems with solutions.

PFN NO: OB-B044N 2.0 C 2.0 C

CLEARANCE: UNCLASSIFIED 4.0 PE1 4.0 PE1

TITLE: COMPANY RADIATION DETECTION INSTRUMENTS

TLO: Operate and maintain RADIAC instruments
in a classroom environment given an
VDR-2 ,UDR-13.

PFN NO: OB-B045N 2.0 C 2.0 C

CLEARANCE: UNCLASSIFIED NOT TAUGHT

TITLE: DIRECTED ENERGY WARFARE

TLO: Identify hazards associated with
Directed Energy Weapons in a classroom
environment given situations requiring
the operation or maintenance of a radiac
instrument, TM 11-6665-214-10, TB SIG
226-8, TM 11-6665-232-12, and TM
11-6665-236-12 IAW TM 11-6665-214-10, TB
SIG 226-8, TM 11-6665-232-12 and TM
11-6665-236-12.

PFN NO: OB-B046N 4.0 C 4.0 C

CLEARANCE: UNCLASSIFIED 2.0 PE2 2.0 PE2

TITLE: RADIOLOGICAL MONITORING AND SURVEY 3.0 PE2 3.0 PE2

TLO:

Perform nuclear damage assessment and
prepare and NBC 4 Nuclear Report and an
NBC 5 Nuclear Report in a classroom
exercise given FM 3-3-1 IAW FM 3-3-1.

PFN NO: OB-B047N 3.0 C 3.0 C

CLEARANCE: UNCLASSIFIED 3.0 PE3 3.0 PE3

TITLE: OPERATIONALS ASPECTS OF RESIDUAL
RADIATION

TLO: Compute all calculations necessary to
advise commander on unit operations and
survival in a fallout-contaminated area
in a classroom environment given student
handouts, FM 3-3-1, GTA 3-6-8, compass
and hairline within 2mm of the
nomogram scale IAW Chapter 6 & Appendix
E, FM 3-3-1.

COURSE: BOLC PHASE 2 CHEMICAL PHASE: 2 VER: 2

*** ACADEMIC HOURS ***

PEACETIME MOBILIZATION

HOURS TYPE HOURS TYPE

PFN NO: OB-B048N 1.0 C 1.0 C
CLEARANCE: UNCLASSIFIED 1.0 PE3 1.0 PE3
TITLE: OPERATIONAL ASPECTS OF INDUCED RADIATION
TLO: Compute all calculations necessary to
advise commander on unit operations and
survival in a neutron-induced
contaminated area in a classroom
environment given student handouts, FM
3-3-1, GTA 3-6-8, compass and hairline
within 1 division of the Keller
nomogram IAW Chapter 7, FM 3-3-1.

PFN NO: OB-B049N 1.0 C 1.0 C
CLEARANCE: UNCLASSIFIED
TITLE: RADIOLOGICAL DECONTAMINATION
TLO: Determine radiological decontamination
types and procedures in a classroom
environment given FM 3-5 and the
requirement to conduct radiological
decontamination IAW FM 3-5.

PFN NO: OB-B050N 3.0 E3 3.0 E3
CLEARANCE: UNCLASSIFIED
TITLE: RADIOLOGICAL EXAM II
TLO: Take written exam based on POI Files
OB-B044N through OB-B049N a classroom
environment with a minimum of 70%
accuracy.

PFN NO: OB-B051N 1.0 OTH 1.0 OTH
CLEARANCE: UNCLASSIFIED
TITLE: RADIOLOGICAL EXAM II CRITIQUE
TLO: Give feedback on POI Files OB-B044N
through OB-B049Na classroom environment
explaining reclaims and exam problems
with solutions

PFN NO: OB-B052N 3.0 C 3.0 C
CLEARANCE: UNCLASSIFIED 1.0 F 1.0 F
TITLE: RESPOND TO DEPLETED URANIUM
TLO: Respond to depleted uranium hazards and
other low level radiological hazards in
a classroom environment avoiding
contamination to yourself or soldiers.

COURSE: BOLC PHASE 2 CHEMICAL PHASE: 2 VER: 2
*** ACADEMIC HOURS ***

PEACETIME MOBILIZATION
HOURS TYPE HOURS TYPE

PFN NO: OB-B071N 0.5 C 0.5 C
CLEARANCE: UNCLASSIFIED
TITLE: RADIOLOGICAL EXAM 1 REVIEW
TLO: Review for exam in a classroom
environment given all necessary manuals
with 70% accuracy on a written
examination.

PFN NO: OB-B072N 0.5 C 0.5 C
CLEARANCE: UNCLASSIFIED
TITLE: RADIOLOGICAL EXAM II REVIEW
TLO: Review for exam in a classroom
environment given all necessary manuals
with 70% accuracy on a written
examination.

APPENDIX B

CMC3 RADIATION TRAINING

COURSE: 4-3-C22-74A PHASE: VER: 99
PREPARATION DATE: 2003/01/10
COURSE TITLE: CHEMICAL CAPTAIN CAREER COURSE

*** ACADEMIC HOURS ***
PEACETIME MOBILIZATION
HOURS HOURS

MODULE: E RADIOLOGICAL SAFETY (RS) 42.0 0.0

MODULE: F TACTICAL RADIOLOGICAL OPERATIONS (RT) 58.5 0.0

TRAINING MODULE: E
TITLE: RADIOLOGICAL SAFETY

PURPOSE: To provide officers with the skills and knowledge required to perform the duties of Radiological Protection Officer.

PEACETIME ACADEMIC HOURS: 42.0
MOBILIZATION ACADEMIC HOURS: 0.0 *** ACADEMIC HOURS ***
PEACETIME
HOURS TYPE

PFN NO: OA-RS01D 1.0 C
CLEARANCE: UNCLASSIFIED
TITLE: INTRODUCTION TO OPERATIONAL RADIATION
SAFETY(OP RAD SAFE)

TLO: Discuss course regulations, exam policies, materials, and homework assignments. Discuss Nuclear Regulatory Commission (NRC) and radiological laboratory safety precautions.

PFN NO: OA-RS02D 2.0 C
CLEARANCE: UNCLASSIFIED 1.0 D
TITLE: FUNDAMENTALS OF NUCLEAR RADIATION 1.0 PE2

TLO: Define components of an atom, characteristics of atomic particles, isotopes of an element, and A and Z notation. Identify characteristics of Alpha, Beta, Gamma, and X-Ray radiation, Describe interaction of ionizing radiation with matter, processes of nuclear decay and concept of half-life. Identify the processes in balancing nuclear equations and performing half-life calculations. Use a Wilson Cloud chamber to visualize Alpha and

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

Beta radiation. Define origin of electromagnetic, E-Ray, Gamma radiation. Define relationship between energy, wavelength, and frequency.

PFN NO: OA-RS03D 1.0 C

CLEARANCE: UNCLASSIFIED 1.0 PE2

TITLE: RADIATION QUANTITIES AND UNITS

TLO: Define activity, exposure, absorbed dose, and dose equivalent and their associated radiation units. Distinguish between radiation terms dose and dose rate. Calculate dose rate at various distances. Compare U.S. and international systems.

PFN NO: OA-RS04D 2.0 C

CLEARANCE: UNCLASSIFIED

TITLE: BIOLOGICAL EFFECTS OF IONIZING RADIATION

TLO: Identify the major effects of ionizing radiation on cell structure; define categories (somatic, genetic, and teratogenic) of effects caused by exposure to ionizing radiation; distinguish between acute and chronic exposure to ionizing radiation.

PFN NO: OA-RS05D 1.0 C

CLEARANCE: UNCLASSIFIED

TITLE: PRINCIPLES AND METHODS OF RADIATION DETECTION AND MEASUREMENT

TLO: Identify methods of detection used by radiac instruments (Alpha, Beta, Gamma, and Neutron), and the physical principles on which they are based.

PFN NO: OA-RS06D 2.0 C

CLEARANCE: UNCLASSIFIED 4.0 PE1

TITLE: RADIAC INSTRUMENTS

TLO: Identify the purpose and methods of detection for Alpha, Beta, and Gamma Radiac Set (AN/PDR-77 RPO Kit), Beta and Gamma Radiac Sets (AN/VDR 2, AN/PDR 27), Alpha Radiac Sets (AN/PDR-56 and AN/PDR-60), and the corresponding civilian commercial instruments. Explain how to determine type of radiation using radiac instruments.

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME
HOURS TYPE

PFN NO: OA-RS07D 1.0 C
CLEARANCE: UNCLASSIFIED
TITLE: HANDLING/STORAGE/CONTROL/REPORTING
OF RADIOACTIVE MATERIAL
TLO: Identify techniques of external exposure
control, methods of controlling internal
radiation exposure, categories of
handling techniques, controlling RADIAC
Instruments in tactical units or TDA
organizations, and considerations for
storing radioactive material.

PFN NO: OA-RS08D 1.0 C
CLEARANCE: UNCLASSIFIED 2.0 PE1
TITLE: SHIELDING PROPERTIES FOR GAMMA PHOTONS
TLO: Identify properties which effect ability
of material to shield against Gamma
radiation. Perform shielding
calculations. Conduct primary
measurements for variety of materials in
the shielding laboratory.

PFN NO: OA-RS09D 1.0 C
CLEARANCE: UNCLASSIFIED
TITLE: WIPE/LEAK TESTING
TLO: Define sealed source. Identify leak
testing methods and leak testing
requirements to include leak testing
intervals/schedule for specific Army
equipment (AN/UDM-2, AN/UDM-6, M43A1,
CAM, MC-1). Distinguish between a smear
and a swipe test.

PFN NO: OA-RS10D 2.0 C
CLEARANCE: UNCLASSIFIED
TITLE: STANDARDS FOR PROTECTION/
REGULATORY GUIDANCE
TLO: Identify by product and special nuclear
material. Define occupational exposure,
occasionally exposed individual,
Radiation Protection Officer (RPO), and
user. Describe procedures for external
and internal dosimetry. Identify
requirements for posting radiation
warning signs, appropriate radiation
exposure forms, appropriate options for
assigning an administrative dose, NRC
reporting requirements for
overexposure, loss or theft of licensed

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

material, and maximum possible dose requirements. Determine maximum permissible dose. Establish ALARA goals.

PFN NO: OA-RS11D 2.0 PE2

CLEARANCE: UNCLASSIFIED

TITLE: COMPUTATIONAL PROCEDURES/MATH REVIEW

TLO: Provide solutions and critiques of assigned problems with computer aid calculations.

PFN NO: OA-RS12D 1.0 C

CLEARANCE: UNCLASSIFIED

TITLE: RADIOLOGICAL DECONTAMINATION

TLO: Define contamination and decontamination. Identify two main objectives, basic principles which must be considered and three methods of radiological decontamination.

PFN NO: OA-RS13D 1.0 C

CLEARANCE: UNCLASSIFIED

TITLE: MONITORING AND ENVIRONMENTAL PROTECTION SURVEYS

TLO: Identify reasons to conduct radiological surveys, appropriate times when Local Radiation Protection Officer should conduct radiation surveys and specific considerations to be made. Identify characteristics of survey methods. Select appropriate instruments to conduct surveys. Perform environmental survey using correct techniques.

PFN NO: OA-RS14D 1.0 C

CLEARANCE: UNCLASSIFIED

TITLE: DISPOSAL OF RADIOACTIVE MATERIAL

TLO: Identify the responsible agency for disposal of unwanted low-level radioactive material in the U.S. Army. Define the five regulatory guidelines for disposal of radioactive material. Identify the four disposal methods. Identify methods for identification of radioactive waste. Outline the requests procedures for disposal of radioactive material.

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

PFN NO: OA-RS15D 3.0 C

CLEARANCE: UNCLASSIFIED 3.0 PE1

TITLE: * TRANSPORTATION OF RADIOACTIVE MATERIAL

TLO: Identify specific Type A packaging requirements. Distinguish between "Normal" and "Special" Form radioactive material, and between A (1) and A (2) values when shipping Type A packages. Identify packaging requirements for shipment of "Limited Quantity" radioactive material, three types of transportation packages, factors that determine which type of package label, appropriate items required in shipping papers, and survey requirements for shipment and receipt of radioactive materials. Determine type of package, appropriate label, transport index and shielding requirements (if appropriate) when preparing radioactive material for shipment.

PFN NO: OA-RS16D 1.0 C

CLEARANCE: UNCLASSIFIED

TITLE: * MANAGEMENT OF RADIATION ACCIDENTS

TLO: Identify the primary considerations of any radiation accident. Distinguish between radiation accidents and incidents. Based on the causation triangle, identify three causes of radiation accidents. Define accident procedures involving unit commodities such as the M43A1, CAM etc. Identify objectives of accident/incident control planning.

PFN NO: OA-RS89D 1.0 C

CLEARANCE: UNCLASSIFIED

TITLE: * OP RAD SAFE REVIEW

TLO: Review material covered in OP RAD SAFE Course

PFN NO: OA-RS90D 2.0 E3

CLEARANCE: UNCLASSIFIED

TITLE: * OP RAD SAFE EXAMINATION

TLO: Demonstrate knowledge of tasks contained in POI files OA-RS01D through OA-RS16D.

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME
HOURS TYPE

PFN NO: OA-RS91D 0.5 S
CLEARANCE: UNCLASSIFIED
TITLE: * OP RAD SAFE EXAMINATION CRITIQUE
TLO: Review of OP RAD SAFE Examination

PFN NO: OA-RS92D 0.5 C
CLEARANCE: UNCLASSIFIED
TITLE: OP RAD SAFE AAR
TLO: Review of content, applicability, and
method of OP RAD SAFE Instruction.

PFN NO: OA-RS93D 3.0 C
CLEARANCE: UNCLASSIFIED
TITLE: DEPLETED URANIUM (DU) (TIER III) AWARENESS
TLO: Awareness training of DU (TIER III) operational
concerns

TRAINING MODULE: F
TITLE: TACTICAL RADIOLOGICAL OPERATIONS

PURPOSE: To provide officers instruction on the effects of nuclear weapons, nuclear burst information, residual radiation hazard area protection, operation exposure guidance, radiological intelligence monitoring and survey operations, the operational aspects of residual radiation hazards, and management of the radiological intelligence cycle which provide essential data for the commander and staff.

PEACETIME ACADEMIC HOURS: 58.5
MOBILIZATION ACADEMIC HOURS: 0.0 *** ACADEMIC HOURS ***

PEACETIME
HOURS TYPE

PFN NO: OA-RT01D 1.0 C
CLEARANCE: UNCLASSIFIED
TITLE: INTRODUCTION TO TACTICAL RADIOLOGICAL
(TAC RAD)OPERATIONS

TLO: Provide the student with an overview of the radiological operations annex to include the sequence of events, materials used, and how the subject matter fits into the general scheme of a chemical officer's responsibilities.

PFN NO: OA-RT02D 3.5 C
CLEARANCE: UNCLASSIFIED
TITLE: NUCLEAR WEAPONS EFFECTS
TLO: Review the types of nuclear weapons, enhanced radiation system concepts, the effects of nuclear weapon detonations to include electromagnetic pulse and transient radiation effects on electronics, and protective measures against each.
Area of Emphasis:
IPB Process (1.0:C)

PFN NO: OA-RT03D 1.5 C
CLEARANCE: UNCLASSIFIED 1.5 PE2
TITLE: NUCLEAR VULNERABILITY ANALYSIS
TLO: Overview of the measures to reduce friendly nuclear vulnerability; prepare a nuclear vulnerability analysis of friendly troops disposition.

PFN NO: OA-RT04D 1.0 C
CLEARANCE: UNCLASSIFIED 2.0 PE3
TITLE: NUCLEAR BURST INFORMATION
TLO: Describe the unit and NBC Center (NBCC) level procedures concerning the NBC Warning and Reporting System, to include estimating the location of (GZ) and

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

nuclear weapon yield; prepare and disseminate NBC nuclear reports. Areas of emphasis: Estimate GZ and yield using manual and automated systems.

PFN NO: OA-RT05D 2.0 C

CLEARANCE: UNCLASSIFIED 6.0 PE3

TITLE: FALLOUT PREDICTION

TLO: Describe the fallout prediction system, upper air wind data sources and formats. Prepare a fallout wind vector plot, an effective downwind message (EDM), a NBC-3 nuclear report for enemy and friendly fallout prediction, and a simplified/detailed fallout prediction; draw the cGy/hr neutron induced radiation contour line for an air burst.

PFN NO: OA-RT06D 1.0 C

CLEARANCE: UNCLASSIFIED 1.0 PE3

TITLE: STRIKWARN MESSAGE

TLO: Apply skills to prepare a STRIKWARN message; recommend protective measures for friendly troops in STRIKWARN area.

PFN NO: OA-RT07D 1.5 C

CLEARANCE: UNCLASSIFIED 0.5 PE3

TITLE: OPERATIONAL EXPOSURE GUIDANCE (OEG)

TLO: Discuss the control of radiation exposure during military operations. Monitor the flow of dosimetry information; evaluate unit radiation exposure status (RES) and advise the commander on OEG levels for units based on unit radiation exposure history, the tactical situation and mission.

PFN NO: OA-RT08D 2.0 C

CLEARANCE: UNCLASSIFIED 4.0 PE3

TITLE: RADIOLOGICAL MONITORING AND SURVEY

TLO: Discuss radiological monitoring policies, procedures and sources of radiation hazards. Compute correlation factors (CF/VCF/AGCF), normalization factors (NF), and overall correlation factor (OCF); compute radiation decay exponent (n) using mathematical method; determine/compute reference time of operational interest (e.g. H+1); process

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

NBC-4 nuclear reports and information recorded on DA Forms 1971-R and 1971-1-R; convert all radiological intelligence information to reference time (e.g. H+1 or H+48); prepare and disseminate residual radiation contamination overlays/data.

Areas of emphasis:

- Focus on using calculators and computers

PFN NO: OA-RT09D 2.0 C

CLEARANCE: UNCLASSIFIED 4.0 PE3

TITLE: OPERATIONAL ASPECTS OF RESIDUAL RADIATION

TLO: Discuss radiation decay; compute transmission factors (TF). Calculate time of entry, time of stay, and total does in a residual radiation area and when crossing a residual radiation. Calculate the optimum time of exit from fallout areas.

Areas of emphasis:

- Review transmission factor calculation
- Review nomogram methods
- Teach/review formula methods
- Use automated system to calculate unknowns

PFN NO: OA-RT10D 2.0 C

CLEARANCE: UNCLASSIFIED

TITLE: OPERATIONAL ASPECTS OF INDUCED RADIATION

TLO: Discuss operational aspects of induced Radiation.

PFN NO: OA-RT11D 1.5 C

CLEARANCE: UNCLASSIFIED 2.5 PE3

TITLE: OVERLAPPING RESIDUAL RADIATION

TLO: Describe the operational implications of overlapping residual radiation areas; compute decay exponent (n) and dose rates for each contributor in an overlapping residual radiation area.

Areas of emphasis:

- Focus on calculators and computer systems

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

PFN NO: OA-RT30D 8.0 PE3

CLEARANCE: UNCLASSIFIED

TITLE: TACTICAL RADIOLOGICAL EXERCISE

TLO: Apply planning and management skills for nuclear weapon employment to include the radiological intelligence cycle and the evaluation of enemy and friendly nuclear weapons employment resulting in recommended courses of action for operational sustainment to the commander.

PFN NO: OA-RT90D 4.0 E3

CLEARANCE: UNCLASSIFIED

TITLE: TAC RAD OPERATIONS EXAMINATION I

TLO: Demonstrate proficiency in performing radiological operations skills and tasks which were instructed in PFNs OA-RT01D through OA-RT06D.

PFN NO: OA-RT91D 0.5 C

CLEARANCE: UNCLASSIFIED

TITLE: TAC RAD OPERATIONS EXAMINATION I
CRITIQUE

TLO: Review the radiological operations tasks taught in PFNs OA-RT01D through OA-RT06D, specifically concerning the examination questions and answers; provide class average and standard deviation; clarify doctrinal understanding.

PFN NO: OA-RT92D 4.0 E3

CLEARANCE: UNCLASSIFIED

TITLE: TAC RAD OPERATIONS EXAMINATION II

TLO: Demonstrate proficiency in performing radiological operations skills and tasks which were instructed in PFNs OA-RT07D through OA-RT09D.

PFN NO: OA-RT93D 0.5 C

CLEARANCE: UNCLASSIFIED

TITLE: TAC RAD OPERATIONS EXAMINATION II
CRITIQUE

TLO: Review the radiological operations tasks taught in PFNs OA-RT06D through OA-RT09D specifically concerning the examination questions and answers; provide the class average and standard deviation; clarify doctrinal understanding.

COURSE: 4-3-C22-74A PHASE: VER: 99

*** ACADEMIC HOURS ***

PEACETIME

HOURS TYPE

PFN NO: OA-RT94D 1.0 S

CLEARANCE: UNCLASSIFIED

TITLE: TAC RAD OPERATIONS AAR

TLO: Summarize key radiological operations instruction issues, allowing students an opportunity to address any unresolved issues and provide immediate feedback to instructors on the radiological operations block of instruction.

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